BASIC ELECTRIC WIRING

A TEXT BOOK FOR FIRST YEAR OF *Polytechnic Institutes*

Published by

SERAJSONS

KARACHI

For

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BASIC ELECTRIC WIRING

(TEXT)

For Polytechnic Institutes

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FOREWORD

EVER since the launching of the Polytechnic scheme by the Government of Pakistan difficulty has been felt in giving instructions to the students on account of non-availability of local textbooks. To solve this problem a Development Wing was created at the behest of the Government in the West Pakistan Board of Technical Education under the control of the " Director of Academics, Curriculum and Text-books' Development ". Fortunately the Ford Foundation also agreed to allocate a good percentage of of its ' Terminal Grant ' for the development of Curricula and Textbooks for the students of Polytechnic Institutes both in East and West Pakistan. Accordingly a series of Inter-Wing Conferences were held and a joint curriculum for both East and West Pakistan was developed for the First year Courses offered by Polytechnics.

It was further decided that 12 textbooks and laboratory manuals for the First Year students should be got written from eminent teachers of the Polytechnics drawn from both East and West Pakistan. It was further decided that books written in one Wing of the country may be got reviewed in the other Wing.

Since the time was very short the authors had to work very hard to develop the manuscripts of these books. We are very grateful to them for cooperation that they extended and the pains that they took to write the manuscripts. It is hoped that both the students and teachers will appreciate the new approach to some of the topics.

Our thanks are further due to Dr. Arden L. Pratt, Ford Foundation Consultant to Directorates of Technical Education in West Pakistan and Dr. Albert E. French, Ford Foundation Adviser to Directorate of Technical Education, East Pakistan. Both these gentlemen have taken extra pains in arranging the Inter-Wing meetings to finalize the joint curriculum. Our thanks are also due to Mr. Habib Alam, Director, Curriculum and Textbooks Development, who made many useful suggestions as regards the presentation of the books and also scrutinized the textual material carefully.

Efforts have been made to present the subject matter and the illustrations in a vivid style so that the contents may be easily understood by the students. It is hoped that the students will enrich themselves with the technical know-how intended to be given through this book.

Since it is the first venture of its type, it cannot be expected to be free from lapses. We hope that the teachers and students of the subject will send us their valuable suggestions for improvement of the book in subsequent editions.

Chairmen,

BOARD OF TECHNICAL EDUCATION,
LAHORE

and

PUNJAB TEXTBOOK BOARD, LAHORE

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CHAPTER I

FUNDAMENTAL CONCEPTS

INTRODUCTION

If you had entered a school at the beginning of nineteenth Century, say 1820, you would have found no studies in electrical technology. Electricity then had no commercial significance and was of interest to but a few persons such as Ampere, Oersted and Charles Coulomb. Charles Coulomb had just proposed the inverse square law to describe the force acting between electified bodies. Volta had recently invented the first battery capable of driving a continuous current. Electric and magnetic effects were not connected by unifying laws and no one could give a satisfactory answer to the question, what is electricity ?

In the past 150 years, an extensive body of electrical science has been evolved and applied so that today electrical engineering sustains an electrical technology of immense social and economic significance. Electrical energy is not generally useful as an end in itself, rather, it is converted into useful mechanical energy in motors, relays and electromagnets ; into heat energy in furnaces and ovens ; into sound energy in loud speakers ; into light energy (often after a conversion into heat) in lamps ; or into chemical energy in electrolytic processes. Since the energy in electrical form can be easily and efficiently converted into other forms, its use has extended and more and more generating stations and transmission lines are springing up. Electrical appliances and machines are coming up daily in newer forms, and there is hardly a modern home in Pakistrn which is not wired and equipped with electrical appliances.

NATURE OF ELECTRICITY

All matter exists in solid, liquid, or gaseous states. The three forms consist entirely of minute divisions known as molecules. Molecules are further assumed to be composed of atoms.

According to modern concepts the atoms of all substances are built up of minute charges of positive electricity called protons, negative electricity called electrons, and neutrons which show no electrical charge. The number of these three constituents of an atom vary in different substances. An atom consists of a central core, called the nucleus, made up of protons and neutrons, and around this a number of electrons revolve in different orbits. The charge of an electron is equal to the charge of a proton, and number of electrons in an atom are equal to number of protons, making atom electrically neutral. All electrons, protons, and neutrons are identical no matter what type of atom they are associated with.

The simplest type of atom is of hydrogen Fig. 1. It consists of only one proton in the nucleus and one planetary electron. The charge of the electron is neutralized by the charge of the proton making

the hydrogen atom electrically neutral.

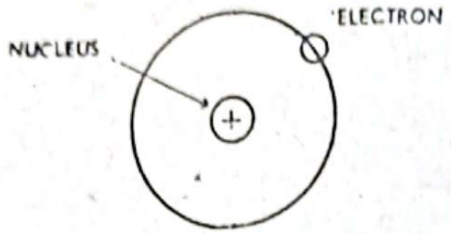


Fig. 1. Atomic structure of hydrogen atom.

The nucleus of the helium atom consists of two protons and two neutrons in the nucleus with two orbital electrons, Fig. 2.

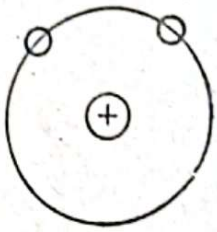
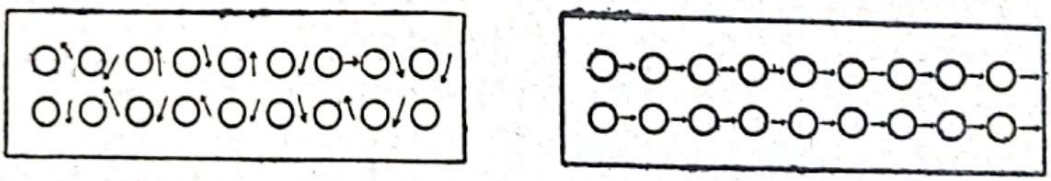


Fig. 2. Atomic structure of helium atom.

The more complex atoms are made up in the same way with a central nucleus and surrounding electrons. For example, an atom of copper has 29 orbital electrons, and 29 protons and 35 neutrons in the nucleus.

The electrons are held to the nucleus by an attractive force, but in some substances called conductors, they are easily displaced. There is a number of free electrons which move in a haphazard manner from atom to atom. When electric pressure is applied between the ends of a conductor this haphazard movement becomes a steady flow along the conductor and it is this moving stream of electrons which constitutes an electric current, Fig. 3. The electron movement, however, is impeded by collison with the molecules, giving rise to an opposition to the flow called resistance. The flow of electron is from negative to positive. That is opposite the conventional direction of current (adopted before the electron theory was established) which is always regarded as being from positive to negative.



(a) Before the application of potential difference. (b) After the application of potential difference.

Fig. 3.

In insulators, the electrons are firmly held. When a potential difference is applied, little or no electron flow occurs.

OHM'S LAW

An electric current flows in a conductor when a potential difference is applied across it. If the conductor is kept the same and the potential difference is changed, the current changes correspondingly. This idea led a German professor of physics Mr. Ohm in 1826 to express the well known law now know

as Ohm's Law. The Law says, "*The current passing through a wire, at a uniform temperature, is proportional to the potential difference between its ends*".

If I is the current in amperes (A.), and E the applied potential difference in volts (V.), then by the Ohm's Law.

$$I \propto E$$

or $$I = gE \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where g is a constant called the conductance.

The reciprocal of conductance is also a constant called the resistance (R).

$$g = \frac{1}{R}$$

Substituting in (1) $$I = \frac{E}{R}$$

The practical unit of resistanee is Ohm (Ω) which is expressed as below :—

If a potential difference of 1 volt applied across a conductor produces a current of one ampere, then the resistance of the conductor is one ohm.

SPECIFIC RESISTANCE

It has been experimentally found that the resistance of a conductor depends upon :

(1) *Length of the material.* The resistance of a wire of constant diameter is proportional to its length (L cm :).

(2) *Area of the material.* The resistance of a piece of material of constant length is inversely proportional to the area of cross section (A sq. cm.)

Combining the two laws we have.

$$R \propto \frac{L}{A}$$

$$R = P\frac{L}{A}$$

Where P is a constant called the specific resistance or resistivity of the material.

If $L = 1$ cm. and $A = 1$ sq. cm. then

$R = P$

Hence the specific resistance of a substance can be defined as the resistance of a cube of unit side. The unit of specific resistance is the same as that of resistance, *i*.e. Ohm.

The specific resistance of different materials is different and varies with the temperature. A material which has low specific resistance is a good conductor, while a material which has high specific resistance is an insulator. The table below gives the specific resistance of some common substances at 20°C.

SUBSTANCE :	Specific Resistance in micro ohms/cm.^{3}
Silver	1.628
Copper	1.724
Aluminium	2.828
Tungsten	5.51
4% Silicon steel	51.15
Manganin	48.2
Nichrome (Ni-Fe-Cr.)	112.2
Phosphor bronze	9.39

EXAMPLE :

(1) The specific resistance of standard annealed copper at 20°C is 1.73 micro ohms per cm.3 Find the specific resistance in inch measure.

Solution : $R = P\frac{L}{A}$

In the above question.

$L = 1$ inch $= 2.54$ cm.

$A = 1$ sq. inch $= 2.54 \times 2.54$ cm.^{2}

Therefore the specific resistance in inch measure

$$= 1.73 \times 10^{-6} \times \frac{2.54}{2.54 \times 2.54}$$

$$= 0.68 \text{ micro ohms/inch}^3.$$

(2) The thickness of a copper bus-bar 42 ft. long is $\frac{1}{2}$ inch Find its width assuming tha its resistance is 0.6 mill ohms. Specific resistance of copper being 2 micro ohms pe centimeter cube.

Solution : Length of the bus-bar $= 42$ ft.

$42 \times 12 \times 2.54$ cm.

1280 cm.

Assuming "b" inches as the width, the cross-sectional area of the bus-bar

$= \frac{1}{2}$. b sq. inches

$= \frac{b}{2}.(2.54)^2$

$= 3.22$ b sq. cm.

Now $R = P\frac{L}{A}$

$$6 \times 10^{-3} = 2 \times 10^{-6} \frac{1280}{3{\cdot}22\ b}$$

or $$b = \frac{2 \times 10^{-6} \times 1280}{3.22 \times 6 \times 10^{-3}} = 0.133 \text{ inches.}$$

TEMPERATURE COEFFICIENT OF RESISTANCE

The resistance of all material changes with the temperature. For most material it increases uniformly with the temperature while for some materials like carbon, glass and electrolytes the resistance decreases with the temperature.

Let α = temperature coefficient, i.e., the increase in resistance of 1 per ohm degree rise in temperature using the resistance 0°C as the basic value.

R_t = resistance at a temperature t°C.

R_o = resistance at 0°C.

Then R_t : $= R_o(1+\alpha t)$.

The temperature coefficient of resistance for copper at 0°C is 1/234.45.

EXAMPLE

The field coil of a D. C. shunt generator has a resistance of 100 ohms at 15°C. What will be its resistance at 60°C ? The temperature coefficient of resistance of copper is 1/234.45 at 0°C.

Solution : Let R_{t1} = resistance at t_1°C
Rt_2 = resistance at t_2°C
Ro_3 = resistance at 0°C
α = temperature coefficient of resistance at 0°C.

Therefore :— $Rt_1 = R_o(1+\alpha t_1)$

$$Rt_2 = R_o(1+\alpha t_2)$$

$$\frac{Rt_2}{Rt_1} = \frac{1+\alpha t_2}{1+\alpha t_1}$$

as $\alpha = \frac{1}{234.45}$

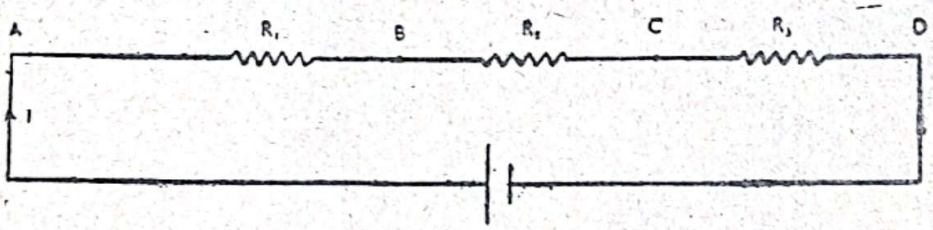
$$Rt_2 = Rt_1 \frac{234.45+t_2}{234.45+t_1}$$

$$R_{60}° = 100 \frac{234.45+60}{234.45+15} = \frac{100 \times 294.45}{249.45}$$

$$= 118.07 \text{ ohms.}$$

RESISTANCES IN SERIES

Resistances are said to be in series when they are connected end to end as shown in the figure below.



We wish to derive an expression for total or equivalent resistance (R) when a number of resistance R_1, R_2 and R_3 are connected in series. As the resistances are in series, the same current "I" will flow across each resistance.

Voltage drop V(AB) = IR_1 by Ohm's law.
Voltage drop V(BC) = IR_2 by Ohm's law.
Voltage drop V(CD) = IR_3 by Ohm's law.

Now

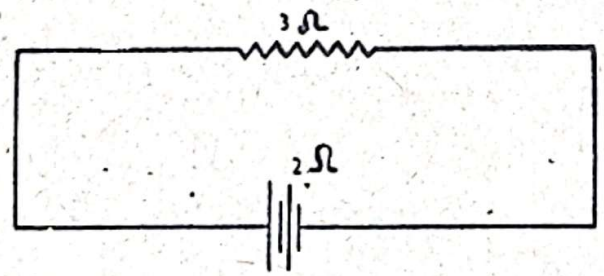
$$V(AD) = V(AB) + V(BC) + V(CD)$$
$$IR = IR_1 + IR_2 + IR_3$$

Dividing by I.

$$R = R_1 + R_2 + R_3.$$

EXAMPLES

A battery with an internal resistance of 2 ohms and an E.M.F. of 10 volts is connected to a resistance of 3 ohms. Find (a) the current in the circuit, (b) the voltage across the 3 ohms resistance.



Solution :—

The internal resistance of the battery is in series with the external resistance of 3 ohms.

The total resistance is

$$R = R_1 + R_2$$
$$= 3 \text{ ohms} + 2 \text{ ohms}$$
$$= 5 \text{ ohms.}$$

By Ohm's law.

$$I = \frac{E}{R}$$

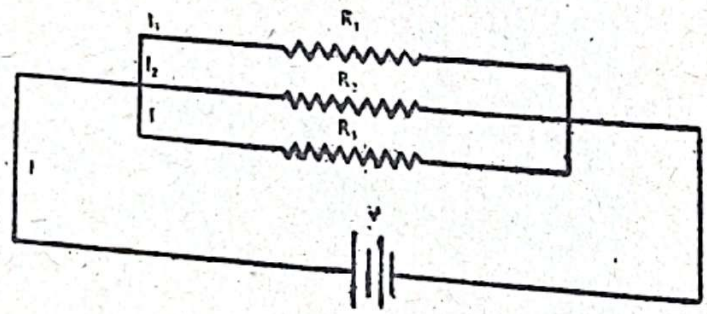
$$I = \frac{10}{5} = 2 \text{ Amps.}$$

The voltage across the 3 ohms resistance is

$$= IR_1$$
$$= 2 \times 3$$
$$= 6 \text{ volts.}$$

RESISTANCE IN PARALLEL

The resistances are said to be in parallel when arranged as shown in the figure below.



Let the current flowing from the battery be I amps. and I_1, I_2 & I_3, be the currents in t resistances R_1, R_2 & R_3, respectively. As the voltage across each resistance is the battery voltage V, Ohms Law,

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$

and

but $$I = \frac{V}{R}$$

therefore $$I = I_1 + I_2 + I_3$$

dividing by V $$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

EXAMPLES

(1) What is the combined resistance of a combination of resistances 2, 3 and 5 ohms when connected in parallel ? Also find the current drawn from a battery of 6 volts when applied across the combination of resistances.

Solution : The combined resistance R is given by

$$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

$$=\frac{1}{2}+\frac{1}{3}+\frac{1}{5}=\frac{15+10+6}{30}$$

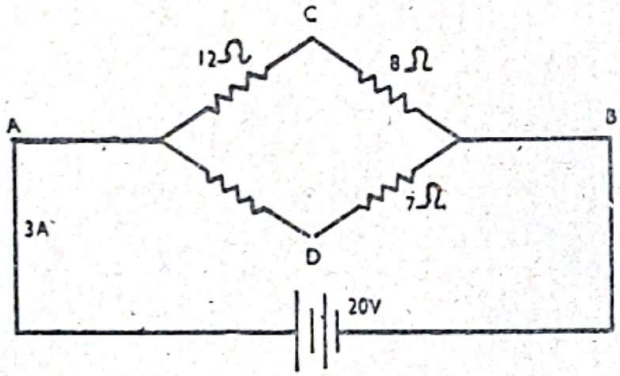
$$=\frac{31}{30}$$

$$R=\frac{30}{31}=0{,}97 \text{ ohms.}$$

The current drawn from the 6 V battery by the combination of resistances

$$=\frac{V}{R}=\frac{6}{0.97}=6.19 \text{ amps.}$$

(2) In the given circuit, calculate the unknown resistance R and the potential difference between C and D when the total current in the network is 3 amps.



Solution :

Current in circuit (A C B) $= \frac{V}{R}$

$$=\frac{20}{12+8}= 1 \text{ amp.}$$

Current in the circuit (A D B) $= 3\text{-}1 = 2$ amps.

$$R+7=\frac{20}{2}=10 \text{ ohms}$$

$$\therefore \quad R = 10\text{-}7 = 3 \text{ ohms}$$

Voltage drop in (A C) $= IR = 1 \times 12 = 12$ volts.

and voltage drop in (AD) $= IR = 2 \times 3 = 6$ volts.

Potential difference between C and D $= 12\text{-}6 = 6$ volts.

ELECTRIC POWER

The rate of doing work is called power. The practical unit of power is the watt (W.), which is defined as the power expanded when a one ampere current moves through a potential difference of one volt. It is given by

$$P = V I \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Since $V = I R$ and $I = \frac{E}{R}$ by Ohm's law.

$$P = (I R) I$$
$$P = I^2R \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

also
$$P = V\left(\frac{V}{R}\right)$$
$$P = \frac{V^2}{R} \ldots\ldots\ldots\ldots\ldots (3)$$

Equation (1) is useful when the voltages and current are known ; equation (2) is useful whe current and resistance are known, and equation (3) is useful when voltages and resistance are know

Since the watt is a small unit, in engineering larger units such as kilowatt and megawatt mostly used. A kilowatt is equal to one thousand watts and a megawatt is equal to a thousand thou (1,000,000) watts.

Another unit of power is horsepower (H. P.) which is defined as 550 foot pound of work second and is equal to 746 watts.

ENERGY

Power is the rate of doing work, or the rate of expenditure of energy. Therefore energy equal to the product of power and time. The units of electrical energy are joule, watt-hour kilowatt-hour. A joule is the work done when a power of 1 watt is maintained for 1 hour or 3 seconds. Thus 1 watt-hour = 3600 joule.

A kilowatt-hour is the work done when a power of 1 kilowatt-hour is maintained for 1 ho
Thus 1 kilowatt-hour = 1000 × 3600 joules
$= 36 \times 10^6$ Joules

The kilowatt-hour is the legal unit for the supply of electrical energy and is known as Boar Trade unit (B.O.T. Unit). This is the unit adopted by electric supply companies. Your energy me in the house records the electrical energy consumed in these B.O.T. units.

EXAMPLE

Determine the electrical bill in the month of January of a domestic installation switched-on follows :

6 — 40 W lamps from 6.30 P.M. to 8.30 P.M.
3 — 100 W lamps from 7.00 P.M. to 9.00 P.M.
1 — 1 KW immersion heater from 6 A.M. to 7 A.M.
1 — 2 KW fire from 6 to 11 A.M. & 5 to 8 P.M.

The losses in cable, etc, are 2%, and the cost of KW-hr is 25 paisa or Re. $\frac{1}{4}$.

Watt hour = Watt × hour.

Watt-hours consumed by 6-40 watt lamps in a day
$= 6 \times 40 \times 2$
= 480 watt-hours

Watt hours consumed by 3-100 W lamps in a day
$= 3 \times 100 \times 2$
= 600 watt-hours

Watt-hours confumed by 1 KW heater in a day

$= 1000 \times 1$

$= 1000$ watt hours

Watt-hours consumed by 2 KW fire in a day

$= 2000 \times 8$

$= 16{,}000$ watt-hours

Total watt-hours consumed by all appliances in a day

$= 480 + 600 + 1000 + 16{,}000$

$= 18{,}080$ watt-hours

KW-hours consumed by appliances in a day

$= \frac{18{,}080}{1000}$

Cable losses $= 18.08$ KW-hours

$= 18.08 \times .2$

$= 0.361$ KW-hours

Total KW-hours consumed in a day

$= 18.08 + 0.361$

$= 18.4$ KW-hours

KW-hours consumed in January (31 days)

$= 18.4 \times 31$

$= 572$ KW-hours

Energy Cost @ Re. $\frac{1}{4}$ or 25 paisa/KW-hour

$= \text{Rs. } \frac{572}{4}$

$= \text{Rs. } 143.00$

EFFICIENCY OF MACHINES

In all machines the output is smaller than the input, as some of the input energy is consumed to overcome losses such as caused by friction or heat. The ratio of output energy to the energy is called the efficiency of the machine.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

The efficiency of all machines is less than unity output (input). The best machine is that whose efficiency is nearest unity. The efficiency is always given in percentage by multiplying the fractional efficiency by 100. If two machines efficiencies y_1, y_2 are mechanically coupled their combined efficiency $y = y_1 y_2$.

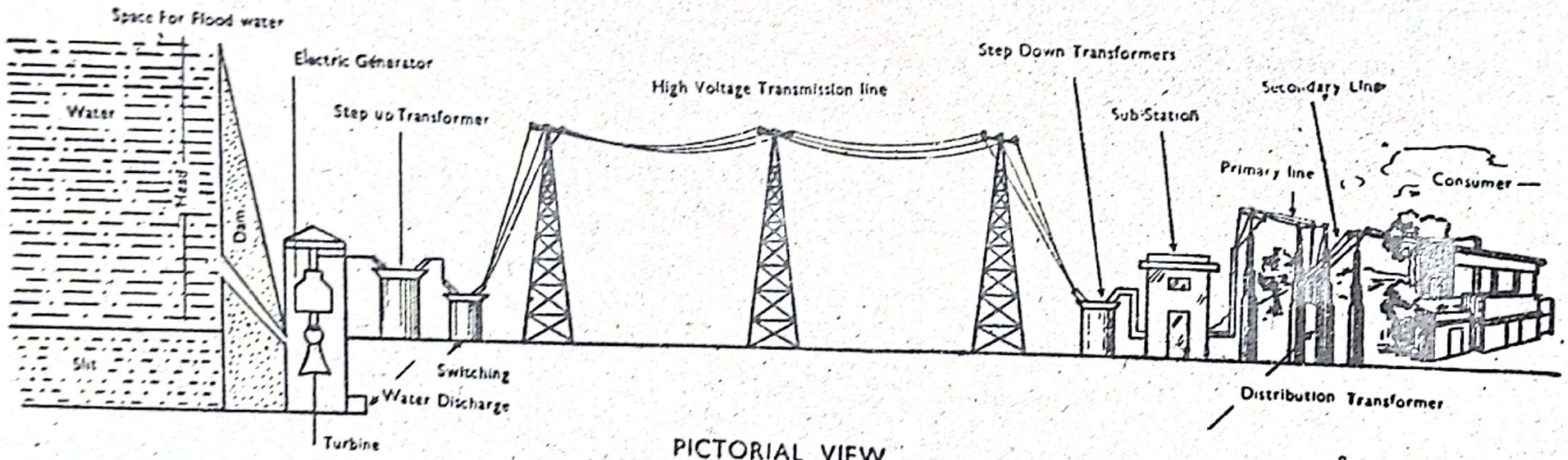
HOW ELECTRICITY COMES YOUR HOME

Electrical energy is generated by a power source such as water, heat, chemical energy, or wind in a power plant. Water power is a very common source of the mechanical energy used for generating electricity in West Pakistan. The discovery of natural gas at Sui in 1953 opened up possibilities of installing electric generators operated by steam or gas turbines to supply electricity. In steam plants, steam is supplied by boilers heated by gas, oil, coal, or wood, whichever is available or most economical. Steam and water turbines are very similar. In that the turbines operate electric generators which produce electric power.

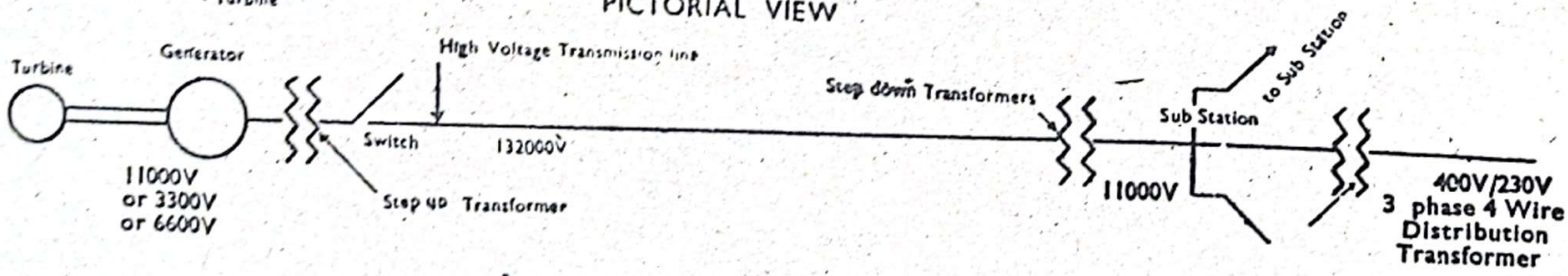
The electric power generated may be either direct current (D.C.) or alternating current (A.C.) Direct current flows through a conductor, such as a wire in one direction. It can be stored in storage batteries and used at the command of the operator. It is too expensive to transmit direct current for any great distance, hence it is daily being abandoned in our country in favour of alternating current.

Alternating current, as the name implies, flows first in one direction and then in the other. One complete flow in both the directions is called a "cycle". The number of such cycles per second is known as the "frequency". The frequency of the alternating current must be high enough, not to be detectable by the human eye. So there is no flickering in incandescent lamps. The most common frequency used in Pakistan is 50 cycle/second. Alternating current can be sent cheaply over wires for hundreds of miles.

A conductor, usually either copper of aluminium, is used to carry electricity from the generating stations. Steel towers of poles with insulators are used to support the wires. These are known as "transmission lines". To make it possible to send electricity economically over long distances it is necessary that it have a high voltage. It is common to have a "pressure" of 132,000 V or more in transmission lines that traverse the country. When used by consumers for lighting, it is usually about 220 volts. After the electricity is generated, the voltage is usually increased or stepped up so that it may be transmitted over long distances. After its arrival in the area where it is used for either city dwellers or industry, the voltage is again reduced or "stepped down". The transformer and equipment used for this purpose is known as a sub station. From the sub stations, primary distributors extend in all directions to serve consumers. The voltage of these distributors are from 3000 to 11000 volts. A transformer substation on the primary distributors located near the consumer is necessary to reduce the voltage so that it can be served for lighting purposes at 220 volts. In rural areas pole mounted substations are mostly used where while in cities the transformer and its equipment is sometimes installed within a building. The distributors which feed your home are radiated from the substations, and are connected to the house wiring network through a service line.



PICTORIAL VIEW

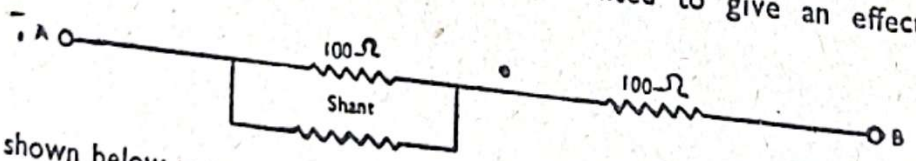


Line Diagramme

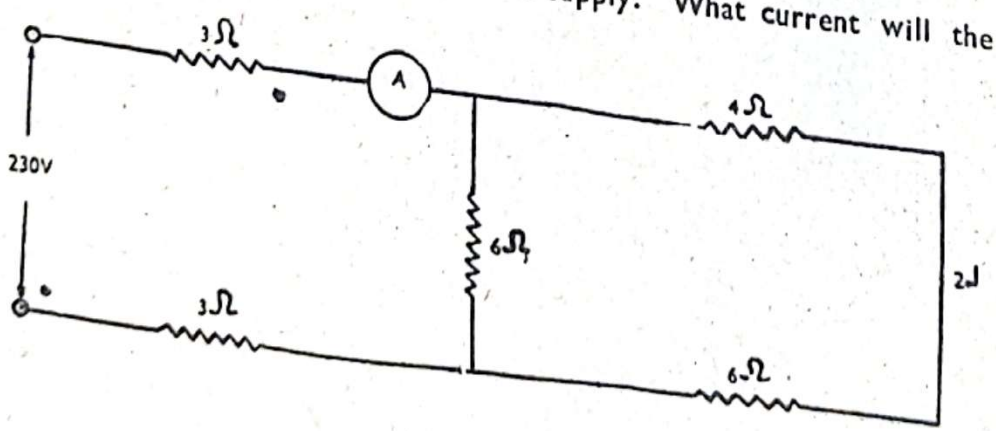
THE PATH OF ELECTRICITY TO HOME

EXERCISES I

1. Find the current in a conductor when 18.72×10^{-18} electrons are moving per second. The charge of an electron being 1.602×10^{-19} coulomb. (One ampere is one coulomb per second.)
2. Calculate the currents taken from a 5 volt D. C. supply by coils whose resistances are (a) 10 ohms (b) 350 ohms (c) 0.08 ohm.
3. Find resistances of coils which take from a 230 - V. D. C. supply the following currents (a) 4 A (b) 12.6 A (c) 30 m A.
4. A single core cable, 10 miles long, is built up of annealed copper conductor 0.25 sq inches nominal cross-sectional area. Find the resistance of the cable. Specific resistance, of annealed copper is 0.677 micro ohm per inch^3.
5. Find the resistance of a 10 ft. steel conduit one inch external diameter and $\frac{1}{8}$ inches thick. Resistivity of steel is 4.5 micro ohms per inch^3.
6. A cable has a resistance of 10 ohm at 20°C and 12 ohms at 70°C. Plot the resistance/temperature graph. Calculate the value of temperature coefficient of resistance at 0°C and at 20°C from the graph.
7. (a) How does a rise in temperature effect the resistivity of (a) copper, (b) manganin and (c) carbon.
   (b) At the instant of switching on, the temperature of the metal filament of a lamp is 15°C and eventually reaches a steady value of 2,500°C. Assuming that the mean temperature coefficient of resistance of the filament material is + 0·0061 ohms per ohm degree centigrade over the temperature range 0°C to 2,500°C. Calculate the ratio of initial and final steady currents.
8. Calculate the total effective resistance of three lamp filaments whose resistances are 4, 8, and 12 ohms, when they are connected (a) all in series (b) all in parallel.
9. Three resistances of 8, 12 and 24 ohms are connected in parallel. Determine the equivalent resistance. What resistance placed in parallel with this equivalent resistance will reduce the total effective resistance to 3 ohms ?
10. With what resistance must the 100 ohms resistor be shunted to give an effective resistance of 95 ohms.



11. The circuit shown below is connected to 230 volts supply. What current will the ammeter, A, read ?



2. Two resistors of 6 ohms and 3 ohms are connected in parallel, and a third resistor of 8 ohms is connected in series with the combination. A potential difference of 25 volts is applied to this circuit. Calculate (a) the total current flowing in the circuit (b) the current in the 6 ohms resistor.

3. Two parallel resistances A and B are connected together in series across a 250 V D.C. supply. Circuit A consists of three branches of resistances 5, 10 and 20 ohms and B consists of two branches of resistance 3 and 9 ohms respectively. Calculate (a) the total effective resistance of the arrangement (b) the current in each resistor (c) power consumed by each resistor and the whole circuit.

4. Find the electric power when 10,000 electrons fall per second through a potential difference of 250 volts. The charge of an electron being 1.602×10^{-19} coulombs.

5. Explain why a 100 V, 40 W lamp should not be connected in series with 100 V, 100 W lamp across 200-V supply. What would happen if they are connected as described ?

6. (a) Which 250 V lamp has greater resistance 100 W or a 250 W ? Explain your answer with calculations.

   (b) A furnace heating-element is to dissipate 25 KW from a 500-V supply. If the Eureka strip to be used has a resistance of 0.00209 ohms per ft., what length of it will be required ?

7. If is found that a nickel-chromium resistance wire, having a resistance of 0.609 ohms per ft., is maintained at 200°C by a current of 3.55 A. If the length of the wire is 10 inches, calculate the power dissipated at this temperature.

8. (a) An electric kettle is marked " 240 V, 750 W ". What current will it take when working under these conditions. What is the working resistance of the element ?

   (b) If the element of the kettle is built up of strip with a specific resistance of 108 micro-nichrome ohms/cm^3 and the allowable current density be 8.5 A/mm^2, find the length and area of the strip.

9. An electric fire has two elements each of 62.5 ohms resistance. When these elements are connected in parallel to a 250-V suppiy, calculate the current flowing in the cable supplying the fire and te energy consumed in 4 hours.

10. Find the cost of electric energy used per month of 30 days by a consumer in the following way. The cost of energy for mixed load is 20 paissa per unit.

    (1) Lighting 100 lamps each 100 W used for six hours each day.

    (2) Heating 10 Kw for 9 hours each day.

11. A domestic consumer has the following load :—

    Power : One 6-Kw cooker ; Three 2 Kw fire.

    Lighting : Six 100 W lamps ; Ten 60 W lamps.

    He uses 50% of the power for an average of 4 hours per day and 30% of the lighting for an average of 3 hours per day. Find his bill for electric energy in February at 15 paissa per unit for power and 28 paissa per unit for lighting.

22. An electrically driven water-pump completely fills a reservoir of capacity 800 gallons in 10 min against a head of 40 ft. The efficiency of motor is 85% and the Water pump 70%. Find (a) h of motor (b) the cost of electrical energy consumed in a month of 30 days when the reservoi filled twice a day. One B. O. T. unit costs 15 paisa.

23. From where is the electricity supplied to your locality. Draw a line diagram from generating station upto supply fuses in your home showing the diflerent stages the electr passes through.

INTRODUCTI

The use of writing accessories
the Pakistan Standard Institution
inimum. I.E.E. Regulations (adopte
ons in so far as they are applicab
wiring installations has been man
kistan Standard Institution (where
n refer to R 1301 which gives the ap

AMP HOLDERS

Lamp holders are designed fo
capable of holding them in firm
ed type of lamp holders are :

(1) The Bayonet Cap (B.C
(2) The medium Edison sc
(3) The goliath Edison scr

Lamp holders are made either

Bayonet cap (B.S.) lamps ar
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Medium Edison screw (E-S.) la
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mp holders are mostly used on
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For lamp exceeding 200 wa
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According to the nature of w

. *Bracket holders* :

This type of holder is intern
The pipe bracket is bent in a shap

CHAPTER II

INTRODUCTION TO ELECTRICAL ACCESSORIES

The use of writing accessories designed and manufactured according to standards laid down y the Pakistan Standard Institution or standards approved by it, reduces accident hazards to a inimum. I.E.E. Regulations (adopted in Pakistan) refer to appropriate British standard specifica- ions in so far as they are applicable. The installation engineer should see that all material used wiring installations has been manufactured in strict compliance with the specifications of the akistan Standard Institution (where applicable) or British Standard specifications. For these he an refer to R 1301 which gives the appropriate B.S.S. number.

AMP HOLDERS

Lamp holders are designed for quick removal and replacement of electric lamps, and should e capable of holding them in firm metallic contact to prevent over-heating. The most commonly sed type of lamp holders are :

(1) The Bayonet Cap (B.C.)
(2) The medium Edison screw (E.S.)
(3) The goliath Edison screw (G.E.S.).

Lamp holders are made either of backelite or brass with porcelain interior.

Bayonet cap (B.S.) lamps are used for ordinary tungsten filament lamps upto 150 ft. size. he lamp cap and the holder both are of the bayonet type.

Medium Edison screw (E-S.) lamps are made to screw into the socket. The screw itself forms one erminal, and the other is at the centre of the socket and lamp cap. Where this type of lamp older is used the screwed contact must be connected to the neutral side of the circuit. These amp holders are mostly used on shipboard for incandescent lamps over 150 watt but not exceeding 00 watt capacity.

For lamp exceeding 200 watt capacity lamp caps of the Goliath Edison screw (G.E.S.) pattern re used. These lamp holders are similar to Edison screw type but are of larger diameter for both screw nd holder. Owing to the large current used by these lamps it is advisable to always switch off the ircuit before unscrewing the lamp.

According to the nature of work the bayonet cap (B.C.) lamp holders are divided as follows :—

. *Bracket holders* :

This type of holder is internally threaded at the top to hold one end of the brass pipe bracket. The pipe bracket is bent in a shape suitable for mounting on a wall.

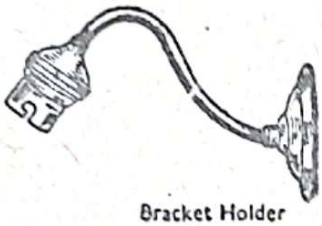
B.C. Cap Lamp

G.E.S.Cap Lamp

Edison Screw Cap Lamp

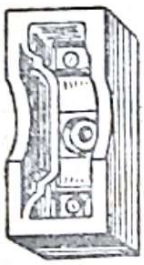
Batten Holder

pendant Holder

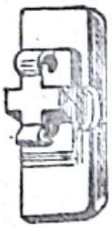


Bracket Holder

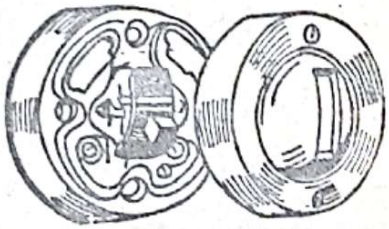
Key Holder



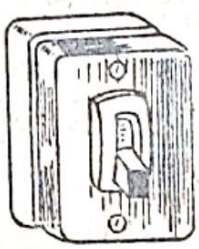
Rewireable



Fuse



Tumbler Switch

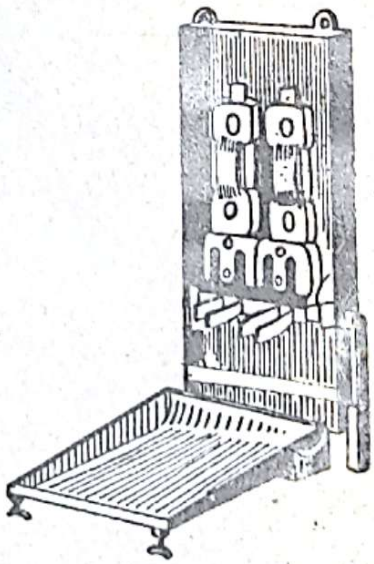


Oblong Type Tumbler Switch

Hardwood push

Flat Back Brass Door push

Pendant push



Main Switch

Under Slung Type Tumbler Switch

Flush Switch

2. *Batten holder* :

The batten holders are used in a batten or wood casing and capping wiring, and are screwed on round blocks. The holders are mostly used in bath rooms and corridors or at the places where only small height of lamp is required.

3. *Pendant holder* :

These holders are used where the lamps are suspended by a flexible cord.

4. *Key holder* :

The key holders incorporate a key switch for "ON" or "OFF" connections of the lamp. They are mostly used in table-lamps. When switched lamp holders are used, a separate switch in the same room must be provided.

SWITCHES

Switches are used to control electricity. They may be operated automatically or by hand. When a circuit is broken an arc tends to form across the contacts. The function of a switch is to break the circuit, but at the same time be capable of preventing the continuance of such an arc.

An essential point in switch design is that the switch should have sufficient current carrying capacity in all parts through which the current passes. Moreover, attention must be paid to the quickness of break, length of break, size and position of terminals, wiring space, spring action of contacts, area of contact and base insulation.

Experiments have shown that on D.C. circuits a quick break action of the switch produces only a small arc between the switch contacts while on A.C. circuits this causes more arcing. Thus for D.C. circuits quick break switches are used while short-slow break switches should be used on A.C. circuits.

Switches' may be broadly divided into main switches and branch switches according to their use. Main switches carry a current of 15 amps or more and are used on main distribution boards. Branch switches are mostly used on smaller circuits and sub-distribution boards.

Switches are also divided according to the number of lines they control simultaneously. Thus a single pole switch controls one line, a double pole controls two simultaneously, and a triple pole controls three lines at the same time.

Single pole switches may be made in a number of ways. A single way switch has one fixed terminal and one moving contact. A two way switch has a moving contact capable of making a connection with either of the two fixed terminals. It may be used to control a lamp from two places.

According to construction the switches may be further classified as :—

(1) Tumbler or toggle switches.
(2) Ceiling switches.
(3) Flush switches.
(4) Fused switches.
(5) Push switches.
(6) Door switches.

1. *Tumbler or toggle switches*

These are the most popular wall type switches and are easy to operate. They are mostly used for controlling lamps, fans and other appliances on final sub-circuits.

2. *Ceiling switches :*

These are tumbler type switches fastened directly to a ceiling out-let and operated by a ch Where they are suitable, such switches are convenient, safe, and cost-saving. In bath rooms t solve the question of danger from shock if an insulated chain is used to operate them. In librar rooms with glass partitions, etc., their use prevents disfigurement of walls by switch blocks, w In work shops and reading rooms they enable local control of single lamp with economy efficiency.

3. *Flush switches :*

The switches are used in concealed wiring. They are provided with a top screw and side sc terminals. Due to smallness of the switches space remains in the switch box for looping the cables.

4. *Fused switches :*

Fused switches are mostly of an iron clad type. They contain fuses in the upper parts operating mechanism in the lower parts. The switches are double pole (DP), triple pole (TP) or tr pole and neutral (TP + N) type. They are made in different ratings varying from 10 to 200 amperes

5. *Push switches :*

This type of switch operates when its push-button is pressed. The switch is used at p where momentary connection is required for example in electric bell circuits.

6. *Door switches :*

The door switch operates by closing or opening the door. It is especially convenient for opera a closet, refrigerator or motor car lights.

SOCKET OUTLETS AND PLUGS

Socket outlets and plugs are required for connecting portable fittings and other elect appliances to the electric supply. The socket is fixed on wall or floor and the plug, which movable part carrying flexible cable to the appliance, is fixed in the socket when an electric connecti required.

Sockets and plugs are available in many designs. But two and three pin types are readily avai in the market. Two pin sockets are used for upto 5 amps while the three pin type can be used upt amps. When three pin sockets are used the thick terminal must be connected to the connection and the line and neutral to the other terminals in clock wise rotation.

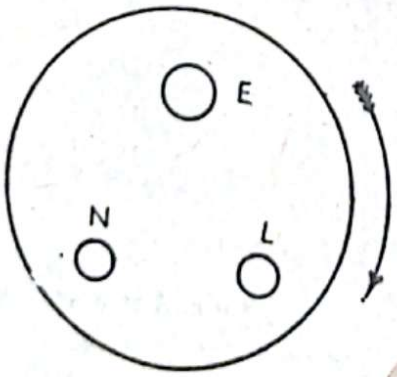


Fig. 2. Connections of three pin so

Each socket with a capacity of 5 amps and above must be controlled by a switch placed on the line conductor. The current rating of the switch must be the same as that of the socket.

In domestic installations three pin shuttered sockets are recommended. These sockets have shutters on hoth the phase and neutral terminals. The shutters open automatically when the plug is put in, but otherwise prevent insertion of metallic things by babies.

LAMP HOLDER PLUGS AND ADAPTORS

Lamp holder plugs are used to take the electric supply to small appliances such as an electric shaver. Lamp holder plugs in various designs and two way B.C. plug adaptors for the connection of two lamps from one B.C. type lamp holder are commonly used. Three way plug adaptors enabling connection of three appliances to a two pin socket are also used.

Adapters for lamp holder plugs are also offered for sale and are widely used in homes by persons ignorant of electricity. Their use is dangerous, I.E.E. regulations suggest that a lamp holder plug or adapter should only be used when the lamp holder is controlled by a switch operated from an easily accessible position, and in no circumstances should they be used with any appliance using more than one ampere and then only in earth free situations.

FUSES

A fuse element consists essentially of a piece of copper or tin-lead alloy wire connected in series in the circuit, which melts and breaks———when carrying more than its rated current. The element, with its accompanying terminals, carrier and base, is called a fuse. The fuse carrier may be of porcelain or other suitable insulating material, so constructed that there is no danger to the operator in removing the fuse carrier. The fuse wire is connected between two terminals and is passed through an asbestos tube or through a hole in the porcelain.

Fuse wire ratings for different sizes of fuses are given in Appendix VI. It may be noted that the fusing current is larger than the continuous current rating of the fuse. Thus a 29 S.W.G. wire will carry 10 amps. of current continuously, and will melt and break the circuit at 16 amps. This wire should be used to control a circuit of 10 amps.

Another type of fuse, called a high rupturing capacity (H.R.C.) fuse, is also used in domestic wiring installations. It also melts on overload in the same way as rewirable fuses, but has more discrimination and will pass harmless current surges without fusing.

DISTRIBUTION FUSE BOARDS

Final electrical subcircuits are drawn from distribution boards. In construction they are metal or hard wood cases containing two or more fuses. The number of spaces available for fuses are called " ways ". Thus a distribution fuse board may have two ways, six ways or twelve ways.

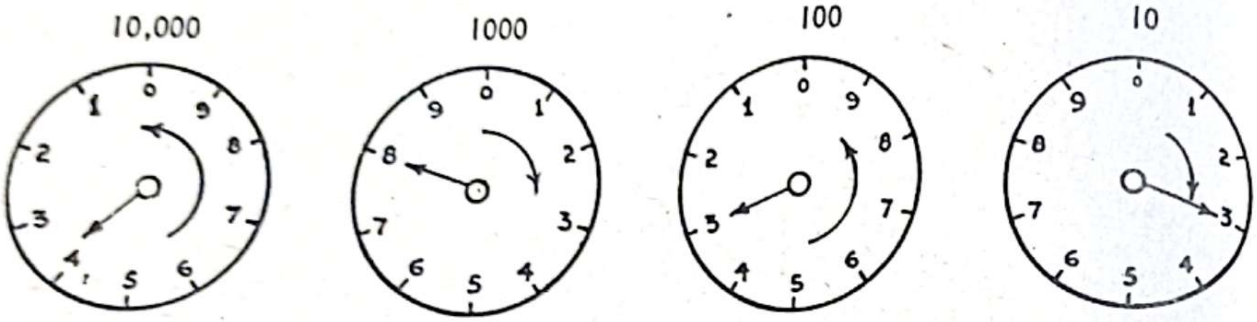
A distribution fuse board may be called double pole (D P) trible pole (T P) or triple pole and neutral (TP +N) type depending on whether single phase, three phase and three phase four wire connections are made to it.

ENERGY METER

The energy meter is used for measuring the amount of electrical energy consumed by an installation. The unit in which the meter measures is the kilowatt-hour. The meter primarily consists of a rotor whose speed is proportional to the amount of energy flow at any instant. The shaft of the rotor is geared to the pointers of the meter dial in such a ratio that their readings denote the kilowatt hours consumed.

Generally an energy meter has four dials. A complete revolution of the pointer on the r
hand dial represents a consumption of 10 KW-Hr. and which is also shown by a movement of the ne
to the next figure on the dial to the left. A complete revolution of the needle on the second dial
the right represents a consumption of 100 KW-Hr., the third, 1000 KW-Hr. and the fourth 1
KW-Hr.

The needle on the right hand dial rotates clockwise, the next counter clockwise, the next c
wise, and the left hand dial counter clockwise. This is shown in the figure below :



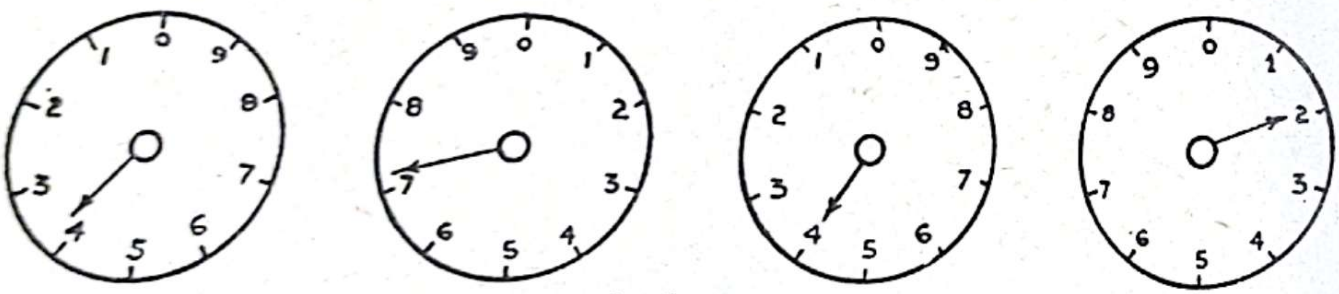
Reading 3833

In every case the last figure passed, not the nearest, is used in the reading. Where the fi
appears to be even, the dial to the right should be consulted to see whether or not zero has b
passed. If it has not, the next lower figure must be used.

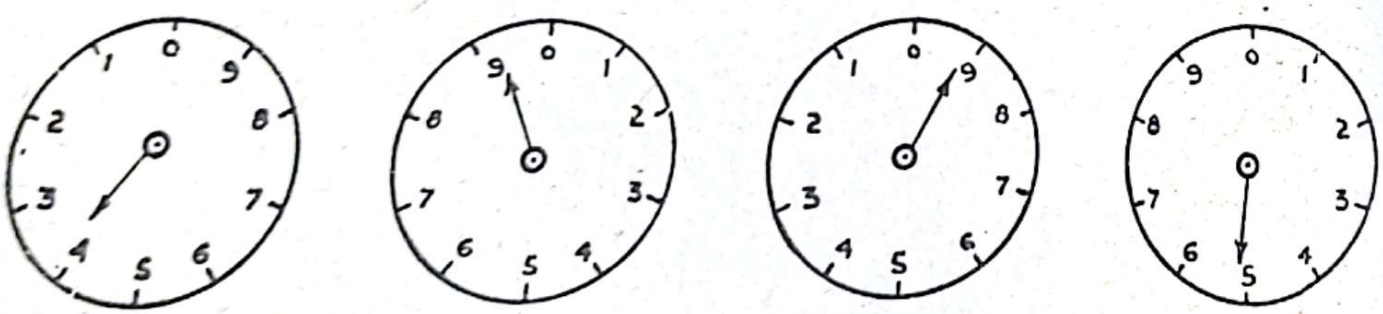
When reading an energy meter, start at the right hand dial, writing down the numbers read
the same order as the dials. When all the number have been written, the meter reading is obtained.

EXAMPLE

Find the energy consumed by a domestic installation when the meter dials 1st of January
1st of February were as shown in the figure below :



1st January



1st February

Reading on 1st January = 3742
Reading on 1st February = 3995
Kilowatt hours used = 3995 - 3742
= 253 KW-Hrs.

CEILING ROSE

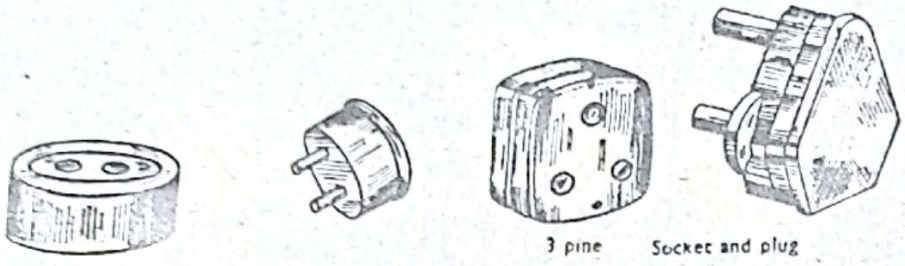
A ceiling rose is a fitting with a detachable cover made of either porcelain or bakelite. It has terminals for the attachment of flexible wires carrying pendants. The ceiling rose contain either two or three connection plates, including a pillar terminal for V. I. R. or P. V. C. wire and a screw terminal with a washer for a flexible wire connection.

CLEAT

Cleats are made mostly of wood or porcelain. They have smooth edges and a grooved base and cover. The cover is fastened to the base by means of screw. Cleats are used in temporary cleat wiring.

PORCELAIN CONNECTOR

This is a block of porcelain having terminals in it. It is used for adjustment or connection of two or more wires in a junction box.



Two pin Socket and plug

3 pine Socket and plug

Pull-Chain Switch and lamp Holder

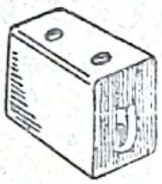
Door Switch

lamp plug Adaptor

Two way B C Adaptor

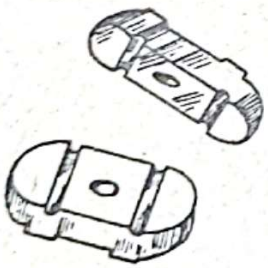
Three Way plug Adaptor

Ceiling Rose

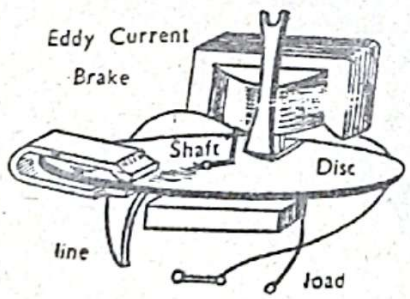


porcelain Cannector

Tenby Midget. Screwon Connector



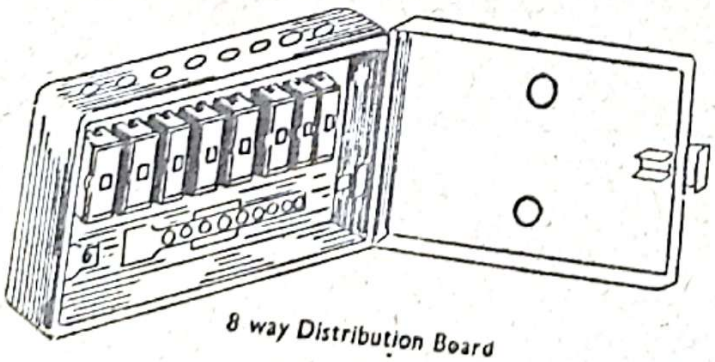
Double-Groove porcelain Cleats



Volt Coil

Current Coil

Single phase Energy Meter



8 way Distribution Board

EXERCISES II

1. What are the specifications for electrical materials used in Pakistan ? How will you find appropriate B.S. number for a certain specification ?

2. What are the different lamp holders classified according to lamp cap ? Which lamp holder would you purchase for each a (a) 100 W, (2) 500 W incandescent lamp ?

3. What type of switches would you recommend at the following places ? Give reasons for your answers.

   (1) Bath rooms.

   (2) Concealed wiring system.

   (3) To control a light by opening of a door.

   (4) To cut off the electric supply of main distribution board.

   (5) To control one lamp from two places.

   (6) To operate an electric bell.

Why are slow break switches more suitable for use on A.C. circuits ? Give reasons to support your answer.

Give short answers to the following questions :

(a) Does a switched lamp holder requires any further control in the sub circuit !

(b) Is it necessary that socket outlets be controlled by a switch, either a part of, or adjacent to the socket, when connected to an A.C. supply ?

(a) What is the purpose of a fuse in an electric installation ?

(b) Using the table, find the S.W.G. number of fuse wire for currents of 5 A, 10 A, 20 A, 30 A and 60 A ?

What equipment is used for

(a) protecting circuits under excess current ?

(b) isolation of system and apparatus ?

Explain your answers with examples.

How do H.R.C. fuses differ from rewirable fuses ? Give advantage and disadvantages of each of hem.

What are the I.E.E. Regulations regarding lamp holder plug and adaptors ? Why should they be voided ?

Why are distribution fuse boards needed for distribution of electricity in buildings ? Explain, ith a neat sketch, the construction of a distribution board you would use on a single phase A.C. rcuit to connect four lighting sub-circuits. Mention the rating of its fuses.

Explain with a neat figure the working of a single phase energy meter.

The electric energy consumed in a domestic installation for a month was 346 B.O.T. units. If

the meter reading for the previous month was 2743 show with a neat diagram the positi needles on the meter dials when the last reading was taken.

12. With neat sketches explain the construction of the following :

(i) Braket holder.
(ii) Batten holder.
(iii) Key holder.
(iv) Ceiling rose.
(v) Cleat.
(vi) Porcelain connector.
(vii) Push switch.

Give the use of each of them.

A cable is an insulated condu
copper is the most widely used cond
Aluminium has recently been introd
has 61% the conductivity of copper

A cable selected for a wiring
efficiently within economical limits.
cores, size and number of strands, i

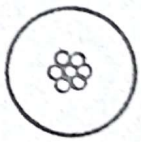
VOLT GRADE

Safely against shocks is achie
Cables are graded according to the
voltage 230/400 volts grade cable ca
and earth and 400 volts between co
according to British Standard Specif
pressure test of 1000 volts A. C. at
breakdown of the insulation, the ca

Cables of other volt grades
and are in the market. These are

CORE

Wires running in gang withi
cores, but those commonly used in



In a multicore cable each c
pressure between the conductors,

CHAPTER III

CABLES

A cable is an insulated conductor which transmits electric power from supply to load. Annealed copper is the most widely used conductor in Pakistan because of its low resistance to electric current. Aluminium has recently been introduced in United States of America as it is cheap and light weight and has 61% the conductivity of copper.

A cable selected for a wiring installation should be such that it can transmit electricity safely and efficiently within economical limits. Cables are classified in a number of ways such as volt grade, not of cores, size and number of strands, insulation coating and mechanical protection.

VOLT GRADE

Safely against shocks is achieved by providing sufficient insulation to prevent current leakage. Cables are graded according to the voltage they are capable of withstanding when in use. Thus a low voltage 230/400 volts grade cable can withstand an electric pressure of 230 volts between the conductor and earth and 400 volts between conductors. In Pakistan, these cables are tested by manufacturers according to British Standard Specification No. 7 = 1953, which requires that the cable should stand a pressure test of 1000 volts A. C. at a frequency of 50 cycles per second for fifteen minutes without breakdown of the insulation, the cable having been immersed in water for twenty four hours previously.

Cables of other volt grades such as 660/1100, 3,00/6000 and 11000/19000 etc. are also manufactured and are in the market. These are not used in domestic installations.

CORE

Wires running in gang within a common sheath form cores. A cable may have any number of cores, but those commonly used in power wiring are one, two, three and four core types.

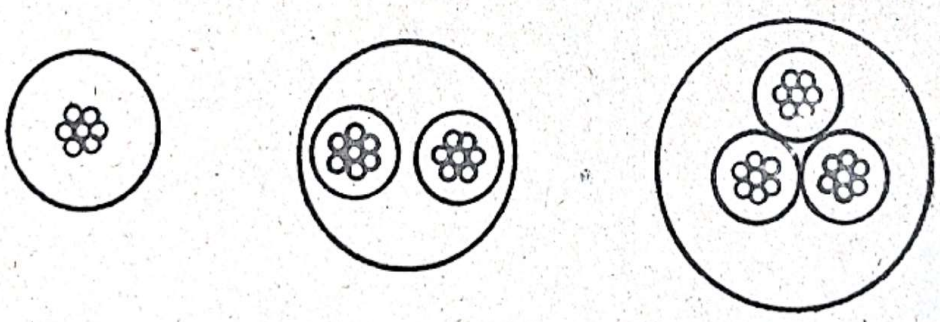


Fig. 1. One, two and three core cables.

In a multicore cable each core is separately insulated with an insulation sufficient to stand the pressure between the conductors, and the conductor and earth.

A three core cable is more expensive than three single core cables of the same size, and to are used mostly where there is either difficulty in laying or neatness in wiring is a major consideratio

STANDING OF CONDUCTOR

Conductors above .044 inch diameter are stranded in all cables. This makes them more fle and easier to handle.

Conductors are bunched together in 3, 7, 19, 37, 61 or 127 strands of the same size. In grou of wires the strands are arranged in concentric rings arround one central wire, each ring having 6 wires in it than the one below it.

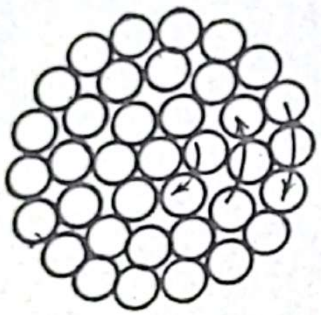


Fig. 2. Arrangement of 37 strand and spiralling direction of layers.

When these numbers are used, the conductor forms very nearly a circular sectional shape. Mo over the various strands of conductor are spiralled round the central strand, and when there is more t one layer as in case of 19, 37, 61 and 127, alternate layers are spiralled in opposite directions. T prevents " bird caging," of the conductors when the cable is bent.

A cable may be specified either by its nominal cross-sectional area or by the number and diame of its strands. Thus a cable having 7 stranded copper wires each of diameter 0.029 inch can be describ as 7/.029 or .0045 sq. inch. The nominal area of the cable is the sum of the areas of the strand conductors.

EXAMPLE

Find the nominal cross-sectional area of 7/.044 cable.

Area of each stranded conductor $= \frac{\pi}{4} d^2$

$= \frac{\pi}{4} (.044)^2$ sq. inch

$= .0015$ sq. inch.

Nominal area of the cable $= 7 \times .0015$

$= .0105 \simeq .01$ sq. inch.

INSULATION

The electricity in cables must be confined to the conductor for human safety. This is achieve providing a high resistance path, radially, throughout the length of the cable.

An insulating material for cables should be cheap, have a high specific resistance, dielec strength, elasticity and tenacity. Further it must be immune to attacks by acids and alkalies ove

range of temperature of about 0°F to 200°F. It should be non-hygroscopic, or if hygroscopic in must be enclosed in a water-tight covering.

The types of insulating materials commonly used are :—

(1) Vulcanised Rubber.

(2) Polyvinyl chloride.

(3) Impregnated paper.

1. *Vulcanised Rubber (V.I.R. Cables)*

Pure Rubber has good insulating and dielectric properties, but it is weak mechanically and is affected by temperature. Vulcanised rubber is formed from pure rubber by treating it with sulphur at a high temperature. It thus becomes mechanically much stronger than pure rubber, and is not affected by temperature changes so much. It may be heated to 200°F without deteriorating.

The sulphur in the vulcanised rubber can react with the copper conductor. However, this effect is completely overcome by tinning each wire of the conductor, since tin does not react with sulphur.

Although vulcanised rubber is relatively strong it needs to be protected against abrassion and therefore, a covering of tape is applied and a braided covering is spun on the top of this The cable is compounded by dipping it in wax or bitumen solution, which to some considerable degree, make it moisture proof.

V.I.R. cables are also manufactured with either a tough rubber sheath (T.R.S.) or a lead sheath to provide mechanical protection. When cables are sheathed this way, one, two or three V.R.I cables are laid flat and a tough vulcanised rubber or lead sheath is dressed around them to a thickness sufficient for mechanical protection. The V.I.R. cables are very commonly used for domestic installations.

2. *Polyvinyle chloride (P.V.C. Cables)*

Polyvinyl chloride is a thermoplastic which is extensively used in place of rubber. P.V.C. cables are particularly resistant to oil, most acids and water, and they do not burn even at high temperature. However, P.V.C. has a tendency to soften and crack even at moderate temperatures. Care must be taken in the use of P.V.C. cables in conditions of high ambient temperature. The I.E.E. Regulations state that the maximum ambient air temperature in which P.V.C. cables should be installed is 113°F or 45°C.

3. *Impr agnated paper (P.I.L.S.A. Cables)*

In domestic installations, impregnated paper insulated cables may be used for under ground services and wiring between buildings. They are also widely used for underground power transmission and distribution purposes.

The great advantage of the paper insulated cables over those of the V.I.R. or P.V.C. types is their superior heat conductivity and ability to with-stand higher temperature without deterioration. A paper insulated cables of a given size can therefore be used to carry higher current than a V.I.R. or P.V.C. cable. The maximum permissible temperature for a paper insulated cable is 150°F, against 113°F for vulcanised rubber or polyvinyl chloride insulated type.

CONDUCTORS

The conductors used in paper insulated cable are of standed copper in circular, sector or o shape. The circular shape is mostly used for single core cable, but for three core cables sector or o shaped conductors are usually employed. These designs permit a smaller over-all diameter of cable f a given voltage rating.

The sector or oval shaped cross-sections of conductor are usually obtained by rolling or hamm ing a circular standard conductor to the desired shape. The use of any shape necessitates a continuo twist in the conductor as it is laid up, since it must occupy a geometrically similar relation to the cab axis at all points along the cable. The twist to the conductor is given immediately after shaping in t stranding machine.

PAPER

Paper tape is wrapped over the conductor to provide insulation. The paper insulation used f many years was manila paper, but wood pulp paper is now in more general use. The physical characte istics, such as tensile strength, elasticity, porosity, and ability to absorb liquids, are of extreme impo tance in determining the choice of suitable quality of paper.

Paper is a hygroscopic, fibrous material and requires treating with an oily compound t it usable in underground cables. High oil absorption and porosity are therefore esser efficient impregnation of paper cores to sufficient thickness.

IMPREGNATION

Impregnation is the process of saturating paper with heavy grade mineral oil mixed with resin improve its properties. Actual proportions of oil and resin depends on the particular manufactur The chief non-electrical properties to be considered in selecting an impregnating compound are lubricating properties, viscosity, chemical stability and freedom from acids.

Good lubricating properties are necessary to faciliate the layers of paper sliding over one anoth without tearing, when they are installed on the conductor.

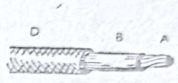
The viscosity of the compound used for impregnation of paper, and its variation with tempe ture are also of importance. The viscosity of the compound must be sufficiently low at the impregnati temperature to facilliate impregnation. On the other hand it must be sufficiently high at the worki temperature to prevent its drainage from one part of the cable to another when it is installed.

Electrically the compound should have high values of resistivity and dielectric strength, and the must be an entire absence of absorbed moisture. A low power factor is also desirable in order to ke down the dielectric losses in the cable. The resin content here again plays an important part in fixing t magnitude of these losses.

LEAD

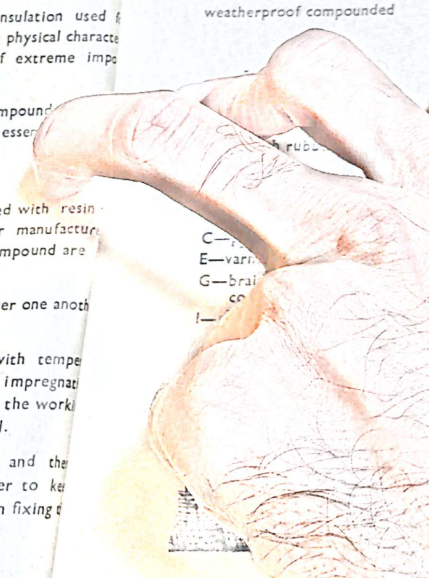
Lead sheathing is applied over the impregnated paper to protect it from outside moisture, and ovide a mechanical protection against handling. Durability and ductility are essential features of t athing. To achieve this, impurities in the lead must be removed before use.

Pure lead is extreme ductile, but is liable to crack when exposed to mechanical vibrations, s y occur on bridge crossings and near railway tracks. Binary and ternary lead alloys are presen o proved higher tansile strength under alternating stresses of this type.



V.I.R. braided & compounded

V.I.R. taped, braided & weatherproof compounded

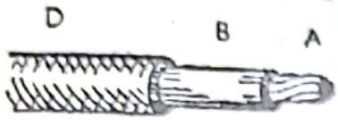


C—
E—vari
G—brai
co
I—

1 Shaped stranded conductor

5 Sheath, lead or lead

PAPER

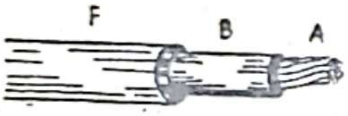


V.I.R. braided & compounded

P,V.C. Insulated

V.I.R. taped, braided & weatherproof compounded

P.V.C. Insulated, braided & weatherproof compounded

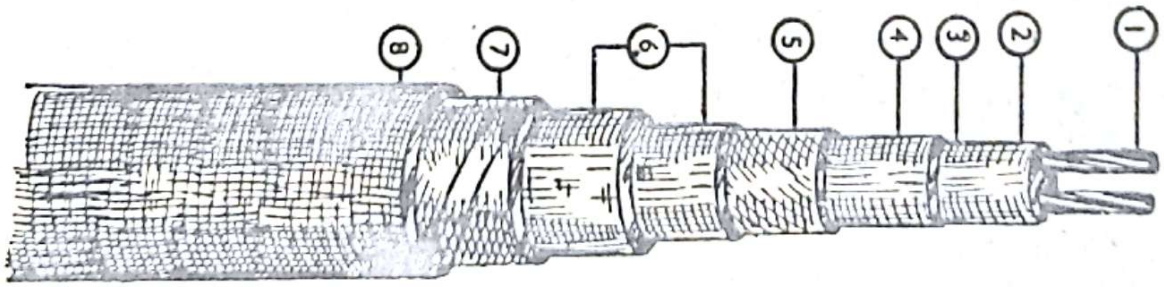


V.I.R. tough rubber sheathed

P.V.C. Insulated, P.V.C. sheathed

A—tinned copper conductors.
B—vulcanised rubber insulation.
C—prooted tape.
D—braid & compound.
E—varnished calico tape.
F—tough rubber sheath.
G—braid & weather resisting compound.
H—copper conductors.
I—plastic insulation.
J—plastic sheath.

V.I.R. & P.V.C. CABLES



1 Shaped stranded conductor *2 Impregnated paper insulation* *3 Fillers* *4 Impregnated paper belt*
5 Sheath, lead or lead alloy *6 Bedding* *7 Steel tape armour* *8 Serving*

PAPER INSULATED CABLES

ARMOURING

Lead in cables being a soft metal develops cracks easily when subjected to strains. If the lea sheath of the cable breaks, moisture enters and destroys the insulating properties of the paper.

Since three core cables used to carry alternating current are subjected to much strain when la in the ground or wound on cable drums for transportation, their lead sheath is enforced by wove galvanised steel wires or two layers of steel tape. This armouring is usually applied over a soft laye of jute, impregnated with bitumen, which prevents the steel-wire armouring from biting into the lea sheath of the cable. The cable is then finished with an overall layer of jute impregnated with bitume called the serving.

Armouring, bedding and serving are completed in one operation. Prior to the application of eac layer, the cable is passed through a bath of hot bituminous compound which helps to form an efficien protection to the sheath and armour against the action of water and chemical acids in the soil. Singl core cables, and sometimes also three core cables installed in generating stations, are plain lead covered When single core cables are buried directly in the ground the sheath is generally protected by a servin of hassian tapes or jute soaked in a preservative compound of a bitumen nature. Single core cables used for alternating currents are not armoured, because there are extensive volt-drop and power loss.

SELECTION OF CABLES

In an electrical installation most faults occur due to the failure of cable insulation by over-heating or mechanical injury. The prevention of these effects by selecting right type of cables adds safety against hazards and reliability to electric service.

The selection of a cable best suited to a given load, within the local conditions and installation method used, is made on the baisis of mechanical characteristics of insulating materials and electrical consideration for the assessment of its size.

MECHANICAL CHARACTERISTICS OF CABLES

Insulating materials used in the construction of cables are mechanically weak and are easily damaged. Different cables are protected against mechanical injury to different levels, and therefore the selection of a cable for a wiring installation must be made on the basis of mechanical soundness of the cable and the protection the installation offers to it.

V.I.R. cables are damaged with continuous contact with oil, grease, acids and rubber solvents. The rubber insulation becomes soft and stickey and looses its insulating properties. Moreover, the rubber insulation burns if ignited, and continues to burn when the flame is removed. Thus fire can spread in the whole building along the cable.

In order to protect the insulation and prevent hazards, braided and compounded V. I. R. cables are installed in steel conduits. Their use on cleats or battens is hazardous, unless encased with some sort of heat resisting baffles. The tough rubber sheath C.T.S. or lead sheath V.I.R. cables are built to withstand mechanical damage and may be installed on cleates are battens. Where danger exists of heavy mechanical injury, the cables should be installed in conduit for extra protection.

P.V.C. insulated cables can be installed in all places where V.I.R. cables can be used. Since P.V.C. insulation is unaffected by oil, grease, acids, chemicals and is resistent to burning P.V.C. cables can withstand mechanical injury better than tough rubber sheath V.I.R. cables and may be installed

directly under plaster, on cleates and batten without the insulation deteriorating. Under plaster installation is cheaper than V.I.R. Insulated cables run in in concealed conduit.

The paper insulated, lead sheath and armoured P. I. L. S. A. cables are strong enough to take mechanical injury. They can be directly buried in the ground to a depth of 18 inches or as recommended by the manufacturer. In direct ground installations sand bedding 6" deep around the cable sometimes improves drainage of water layer of bricks provides extra mechanical protection.

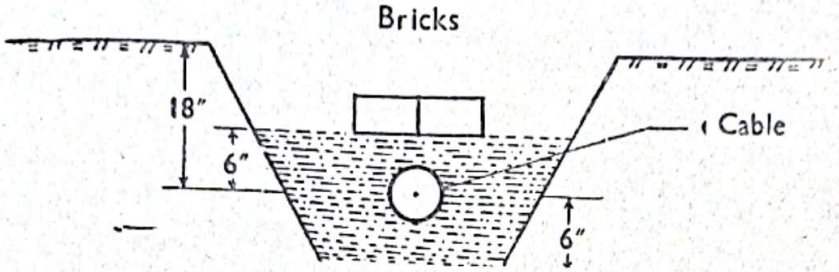


Fig. 4. Laying of under ground cables.

When these cables cross roads where the traffic is heavy, they must be installed in a steel pipe for extra mechanical protection. The pipe should be preferably encased 6" of concrete. A scope of 1 to 100 faciliates drainage of water in the pipe.

A summary of cables suitable for different wiring installations as recommended by Pakistan Cables Ltd. and British cable manufacturers is given on page 31. It may be used to select cables according to their mechanical properties.

USE OF CABLES IN DIFFERENT INSTALLATIONS

S. No.	Method of Installation	Recommended Cables
1	Heavy gauge conduit (Concealed or on surface)	(1) V.I.R. braided and compounded. (2) P.V.C. insulated. (3) P.V.C. insulated braided and compounde
2	Light gauge conduit OR Wood casing	(1) V.I.R. bralded and and compounded. (2) P.V.C. insulated. (3) P.V.C. insulated, braided and compounde
3	Cleat	(1) V.I.R. braided and compounded. (2) P.V.C. insulated, braided and compounde
4	Battens	(1) V.I.R. tough rubber sheathed. (2) V.I.R. Lead sheathed. (3) P.V.C. insulated P.V.C. sheathed.
5	Service line OR Wiring between buildings OR Surface exposed to weather	(1) P.I.L.S.A. cables or P.I.L.S. cables. (2) V.I.R. taped, braided and weather proof compounded (3) P.V.C. insulated, braided and weather pro compounded. (4) P.V.C. insulated, P.V.C. sheathed.
6	Lighting fittings	(1) V.I.R. glace cotton braided flexible cord. (2) P.V.C. insulated flexible Cord.

ESTIMATION OF CABLE SIZE

A cable must carry the current of the connected load. Estimation of its size is based on its current carrying capacity and voltage drop.

The current carrying capacity of a cable is the maximum current it can carry before the temperature exceeds a permissible value (usually 113°F). The capacity depends on the size of the conductor, atmospheric temperature and provision of cooling facilities through the surrounding medium. Appendix III provides the current ratings of different cables. It may be noted that the current rating of a cable at certain ambient temperature varies with grouping and conditions of installation. These factors relate to the cooling facilities of the cable, and must be considered in determining its current rating under the existing temperature of the installation.

The voltage drop is an important factor in the assesment of conductor size because a heavy volt drop in cables will prevent appliances functioning at their rated capacity.

According to I.E.E. Regulation 204 (A), the voltage drop from the incoming supply terminals to any point in the installation should not exceed (1 + 2%) of the declared voltage. Thus in a domestic installation, supplied at 250V, the maximum allowable voltage drop from the supply fuses to any lamp, plug or fan terminals shall be

$$1 + \frac{2}{100} \times 250$$
$$= 1 + 5 = 6 \text{ volts.}$$

EXAMPLE 1

A pair of mains 25 yards long are connected to a declared supply of 220 volts. The total connected load of lamps and fan at the far end of the cable is 300 watts. If the diversity factor of the load be 66.6% and the mains are installed in conduit, find the size of main-cable when the maximum temperature of the place is (a) 95°F (b) 110°F.

Solution

The maximum power expected to flow at any time
= connected load × diversity factor
= 3000 × .666 = 2000 watts.

Maximum current $= \frac{W}{V} = \frac{2000}{220} = 9.1 \text{ A}$

Total drop allowed $= 1 + \frac{2}{100} \times 220 = 1 + 4.4 = 5.4$ volts.

Now $V = R I$

or $V = P \frac{l}{A} I$ (where A is area)

$$5.4 = .66 \times 10^{-6} \frac{25 \times 2 \times 36}{A} \times 9.1$$

or $$A = \frac{.66 \times 10^{-6} \times 25 \times 2 \times 36 \times 9.1}{5.4}$$

$$= .002 \text{ sq. inches.}$$

Thus the minimum area of cable shall be 0.002 sq. inches. Using appendix III, table1
rating factor at 95°F = 0.86

Since there are only to be two cables installed in the conduit, the grouping factor is unity.

The current rating of a cable under the given temperature conditions

$$= \frac{\text{Maximum current}}{\text{temperature rating factor} \times \text{grouping factor}}$$

$$= \frac{9.1}{.86 \times 1} = 10.6 \text{ amp.}$$

From the table it may be noted that 3/.029 single core 230/400 volts grade V.I.R. or P.V.C. insula cable is suitable since it can satisfy both voltage drop and current rating requirements.

(b) In this case the rating factor at 110°F is not known. It can be calculated as follows :

$$\text{rating factor at } 110°F = .69 - \frac{.69 = .47}{113 = 104} \quad (110 = 104)$$

$$= .69 - .024 \times 6$$

$$= .69 - .114$$

$$= 0.546$$

the current rating of cable at 110°F should be

$$\frac{\text{maximum current}}{\text{temperature rating factor} \times \text{grouping factor}}$$

$$= \frac{9.1}{.546 \times 1} = 16.7 \text{ amp.}$$

From the table it can be noticed that 3/.029 cable has an area of .002 sq. inches and current ra 10 amp. It fulfills the area requirement based on voltage drop, but fails on current rating. 7/ which has area greater than .002 sq. inches and current rating of 20 amp satisfies both the area current requirements. Thus the cable under these situations shall be 7/.029, single core 230 volt-grade V.I.R. or P.V.C. insulated cable.

This example illustrates the effect of temperature on the size of a cable. In the first case v ambient temperature was 95°F 3/.029 cable served the same purpose as 7/.029 at 110°F.

EXAMPLE 2

If the mains of example 1 above are bunched along with two other mains having four wires, the size of the cable under this situation.

Solution

The minimum area of the cable shall again remain .002 sq. inches, the grouping factor fo cables is .7.

(a) when ambient temperature is 95°F current rating of cable is

$$\frac{\text{Maximum current}}{\text{temperature factor} \times \text{grouping factor}}$$

$$= \frac{9.1}{.86 \times .7} = 15. \text{ Amp.}$$

The cable under these situations shall be 3/.036 single core, 230/400 volt-grade V.I.R. or P. cable.

(b) when the ambient temperature is 110°F, the current rating of cable is

$$\frac{\text{maximum current}}{\text{temperature factor} \times \text{grouping factor}}$$

$$= \frac{9.1}{.546 \times .7} = 23.8 \text{ amp.}$$

The cable in this case shall be 7/.036 single core 230/400 volt-grade, V.I.R. or P.V.C. insulated.

EXAMPLE 3

In example 1, if the length of main is 100 yards find the cable size.

The area of the cable to meet the volt-drop requirement at the load now is

$$V = RI$$

or
$$V = P \frac{l}{A} I$$

$$5.4 = \frac{.66 \times 10^{-6} \times 100 \times 2 \times 36 \times 9.1}{A}$$

or
$$A = \frac{.66 \times 10^{-6} \times 100 \times 2 \times 36 \times 9.1}{5.4}$$

$$= .008 \text{ sq. inches.}$$

(a) When the temperature is 95°F, the current rating of the cable as calculated is 10.6 amp. Thus the cable size to meet area and current rating is 7/.044.

(b) When the temperature is 100°F the current rating as calculated is 16.7 amp. amp. The cable size to meet area and current rating is again as above is 7/.044.

In this example, it may be noted that the area of the cable calculated on volt-drop considerations dominates the current rating, and the selection of cable is thus based on it.

GROUPING OF CONDUCTOR IN A.C. CIRCUITS

When A.C. current passes though a single cable an alternating flux is liked with it. The flux is responsible for causing a voltage drop in addition to the drop due to resistance of the cable. Moreover the flux sometimes produces an unwanted hum in the cable Grouping of outgoing and return cables of the same circuit cancel the alternating fluxes because of their opposite nature. thus the additional voltage drop and hum caused by the flux automatically ends. The conductors of an A.C. circuit, therefore should be grouped as closely as possible. If enclosed in steel conduit, all the conductors of the same conduit. A two phase circuit having four line wires may be treated as two single phase circuits, and the two wires of each phase may be placed in separate conduit if desired.

If more than one wire is used for each lead or line of the circuit and it is not convenient to pull all the leads in one conduit, the leads may be formed into separate groups. However each group must contain one of each of the different line wires or poles of the circuit. These groups may then be placed in separate conduits if needed. The three line wires of a three phase circuit must also be drawn in one conduit.

FLEXIBLE CORDS

A flexible cord is used for connection of portable domestic apparatus and pendants fro ceilingroses.

Flexibility in the cord is achieved by providing the conductor with a greater number of stran than in ordinary cable for the same cross-sectional area. The conductor is surrounded by a rubber P.V.C. insulation. The rubber insulated cords are usually glace cotton or artificial silk braide This type of braiding is flexible and provides desired mechanical protection to the rubber. The P.V.C insulated cords are P.V.C. sheathed. These are more robust than rubber insulated cords, and are mor suitable where there is much risk of mechanical damage.

A twin flexible cord may be used for fittings or apparatus where earthing is not necessary. Fo appliances such as electric irons, refrigerators, coffee perculators, etc., where metal is to be earthed, three core flexible cord is suitable. The cores of the cord are coloured as follows "line"—red "neutral"—black and "earth"—green.

Conventional rubber and P.V.C. cords are suitable in situations where the conductor temperatur does not exceed 65°C. When used at higher temperatures their life is considerably decreased. In heatin appliances and semi-enclosed lighting fittings heat is transmitted to the supply cord by direct conductio via the Socket to the cord conductor and also by an increase in ambient temperature within the vicinit of the supply cord. The effect of this higher temperature is to damage the cord insulation in a consider ably shorter period. High temperature flexible cords for use at 85°C, 130°C and 180°C are now available For a maximum operating conductor temperature of 85°C, the cables are insulated with a composit covering of varnished cambric, heat resisting fibre asbestos and glass fibre. Use of this type of flexibl cord should be limited to dry situations owing to the hygroscopic nature of the insulation.

Flexible cords for a maximum operating conductor temperature of 130°C and 180°C are insulate with heat-resisting glass fibre. In these each conductor is lapped with two layers of glass fibre which ar impregnated with a suitable varnish. A braid of similar fibre is applied over this primary insulatio and impregnated with varnish. The insulated conductors are then laid up in the number of cores and form required.

Appendix III, Table VI provides the electrical and mechanical characteristics of flexible cords. Wires of flexible cords for pendant work should be of a size sufficient to carry the current without any undue rise of temperature. Moreover the cord should be strong enough to support the pendant.

EXAMPLE

A 200 W, 230-V lighting fitting is suspended by two flexible cords. The total suspended weight is 16.5 lb. select the correct size of flexible cord from the table VI appendix III. Assume that the weight is evenly spread over the two cords.

Since the weight is spread evenly over the two cords, the load on each cord

$$= \frac{16.5}{2} = 8.25 \text{ Lb.}$$

$$\text{current flowing in the cord} = \frac{200}{230} = 0.866 \text{ A.}$$

From the table the cord which can carry 0.866 A current and support 8.25 Lb. load is 40/.0076.

———

EXERCISES III

1. Why are cable conductors stranded ? Make a neat figure and show the arrangement of strands and the spiralling direction of layers in 19/.044 cable.

2. Give reasons why.
   (a) Copper conductors in V.I.R. cables are tinned while in P.V.C. cables they are not tinned.
   (b) Aluminium conductor cables for the same rating are greater in cross-section than copper conductor types.
   (c) Rubber insulation of V.I.R. cables is of vulcanised rubber.
   (d) Bunching of cables decreases their current rating.
   (e) The "go" and "return" leads of the same alternating current circuit should be grouped together.

3. Describe the component parts of the following types of cables and show a cross-sectional sketch in each case. Also make a sketch of a cable end made ready for connection into a terminal, in each case.
   (1) V.I.R. single-core cable.
   (2) T.R.S. cable, twin core with earth wire.
   (3) Three core paper insulated lead sheathed and steel tape armoured cable.

4. Which type of cable you will use for eacn of the following ?
   (i) batten wiring.
   (ii) wiring in conduct in damp places.
   (iii) connection for pendants from ceiling roses.
   (iv) overhead service cable.
   (v) wiring between buildings.
   (vi) connection of immerson heater.

   Give reasons for your answers.

5. Illustrate with a neat sketch the constituent parts of paper insulated lead sheathed and armoured cable. Why are these cables provided with (a) lead sheath (b) braiding (c) armouring and (d) serving ?

6. At what minimum depth of under-ground service is paper insulated cable laid in the ground ? Draw a cross-section of a cable trench showing the different materials used for elimination of (a) moisture and (b) mechanical stress.

7. Why is the paper of paper insulated cable impregnated with oil ? What should be the properties of the impregnating oil ?

8. What do you understand by "bunching" ? How is "bunching" taken into account while selecting the cable size ?

   Using the tables, find the reduction in current in 3/.029 P.V.C. cables when they are bunched (a) six together and (b) twenty together.

9. (a) What is the effect of temperature on a cable rating ?

(b) How many more times can 3/.036 inch V.I.R. cable be loaded in a place where the shade temperature is 80°F than in a place where the temperature is 110° F ?

10. From Table I, Appendix III, select cables of suitable carrying capacity for the following loads and contions (V.I.R. cables drawn into heavy gauge screwed, welded conduit).

(i) 240 V single phase sub-main serving a lighting load totalling 10.5 Kw. Length of run is 8 ft. Conditions normal. average shade temperature 104°F. diversity 66%.

(ii) 230-V single phase, heating load of 6 Kw, efficiency 80%. Average shade temperature 100°F, length of run 100 yds.

11. Using Appendix III, Table I find what length of 3/.036 inch V.I.R. cable could be used to carry a load of ten 100 W and five 200 W lamps on a 230-V D.C. circuit, and at the same time not exceed the voltage drop allowed.

12. A cable supply distribution fuse board is 150 ft. distant from the supply terminals of 230 volts. The load for lighting and power is estimated at 4.5 Kw. Assuming a maximum drop of 2 V on final sub-circuit and a shade temperature of 110°F, find the size of the cable.

13. What do you understand by the term "volt-grade" ? Under what conditions can a 230 volt-grade cable be instelled on a 3-phase 400 volt circuit ?

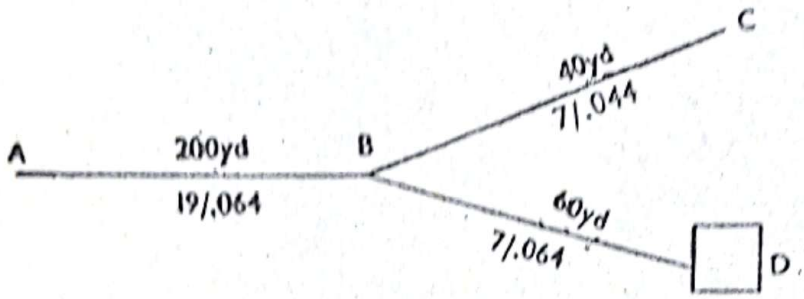
14. The nominal cross-sectional area of a 7/.036 inches cable is given in the tables as 0.007 sq. inch, and the direct current rating for twin cable with rubber insulation is 28 A. Using these figures for area and current, and taking the specific resistance of the conductor material as 0.634 micro ohm inch. Calculate the length of twin cable which will give a 1 volt drop.

15. A two core cable with a resistance of 0.2 ohm (go and return) carries a current of 200 A. If the power station voltage is 230 V, calculate (a) the consumer voltage (b) the power loss in the cable (c) the cost of this loss if the cable is continuously energized for a period of one year and electrical energy costs 15 paisa per unit.

16. Assuming a temperature of 20°C, calculate the cross-sectional area of each conductor of a 2-core cable to supply a 5-B. H. P.D.C. motor having a full load efficiency of 80% and situated 100 yds. from the supply point. The voltage drop in the cable is not to exceed 2% of the motor voltage, which is 200 V. Take resistivity of the conductor material as 0.67 micro ohms per inch^3 at 20°C. (b) What would be the voltage drop in this cable at an operating temperature at 40°C if the current remained unchanged ? The temperature resistance of copper is 0.00428/deg c at 0°C.

17. The V.I.R. cable system shown in the diagram is loaded at C with 30 amps, and at D with a distribution board. A constant voltage of 230 volts is maintained at the supply terminal at A. When the distribution board is at full load the potential difference at C is 224 volts. Find the

full load current fed by the distribution board and its terminal voltage.



8. (a) What type of flexible cords must be used where
   (a) there is a risk of mechanical damage ?
   (b) temperature of conductor is about 180°C ?
   (c) the equipment is to be earthed ?

   (b) A 300 W, 230-V lighting fitting is suspended by three flexible cords the total suspended weight is 18.5 lb. Select the correct size of flexible cord from the table VI, Appendix III. Assume that the weight is evenly spread over the cord.

CHAPTER IV

JOINTS AND SPLICES

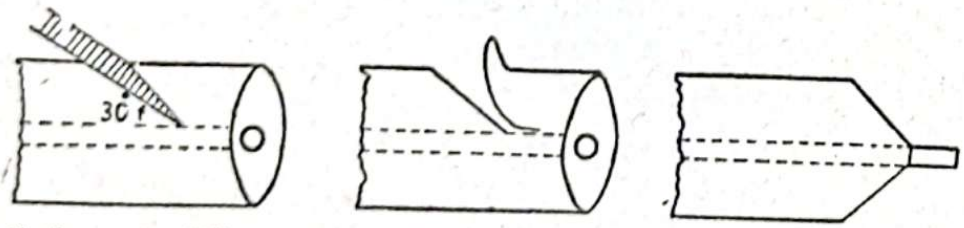
Joints are of utmost importance, as they are the weak places in an otherwise homogeneously insulated conductor. In a poor joint there is high contact resistance and poor mechanical strength. High resistance at the joint drops voltage and consumes electric power. A drop in voltage decreases electric pressure to appliances which cease to function with their rated capacity. Power consumption at the joint causes over heating and extends chances of fire in the wiring installation. Poor mechanical strength of a joint sometimes causes a break which shuts off the power supply. Much damage to an electrical installation can be prevented if the conductor is jointed so that the junction is electrically and mechanically at least as good as the conductor itself.

Preparation of good joints or splices needs careful execution of the following operations with insulated conductors :

(i) Skinning.
(ii) Scraping.
(iii) Jointing and splicing.
(iv) Soldering.
(v) Taping.

1. SKINNING

Skinning process of removing the insulation when is the making joints or splices with an insulated conductor. In the removal process a sharp knife should be used with the blade held at an angle 30 degrees to the wire until the conductor is reached and then the blade is forced parallel to the conductor.



Knife moving 30° to conductor through insulation. | Knife moving parallel to conductor. | Conductor with insulation removed.

Fig. 1. Removal of insulation.

Care must be taken not to remove the insulation with the cutting edge of the knife at an angle of 90 degrees to the wire. This damages the wire and it will break easily when bent at the point where the damage is located.

1. SCRAPING

After most of the insulation is removed the conductor should be thoroughly scraped by a knife or emery paper. In order to scrape with a knife, during scraping the back of the knife blade should be kept at 90 degrees to the conductor, and the conductor cleaned until it has a shiny appearance. A clean surface will ensure a good metallic contact and facilitate soldering. Care should be taken not to scratch the conductor with a sharp blade because it may injur the conductor or remove tin if V.I.R. insulated

JOINTING AND SPLICING

By definition jointing is the process of tying together two single conductors so that the union shall be sound electrically and mechanically. Interlaying of strands of two conductors is called splicing.

The use to which a joint or splice is put depends upon the requirements of the wiring. In some situations, such as junction boxes in conduit wiring, high electrical conductivity is desired, while mechhanical strength is not of much importance. In other situations, such as over-head lines, both are required.

There are a number of joints and splices which are widely used in electrical wiring installations. Some of them are :

(i) Simple twist joint.
(ii) Western union joint.
(iii) Britania joint.
(iv) Scarf joint.
(v) Duplex joint.
(vi) T - Joints and splice.

(i) Simple twist joint :

This joint is also called the Bell hanger's joint and was originally intended for bell circuits, however because of its compactness and its being electrically and mechanically strong, it is now used in these situations where tension is not too great.

The joint is formed by giving a single twist at the centre and not less than five turns of each wire about the other. In order to make the joint remove about 3 inches of insulation from the end of each wire and clean them. Bring together both the wires as shown in Fig. 2 (b) and make a turn at the centre. Hold one wire and twist the other with pliers making not less than five turns. Similarly twist the other wire. The appearance of the complete joint before soldering is given in Fig. 2 (c).

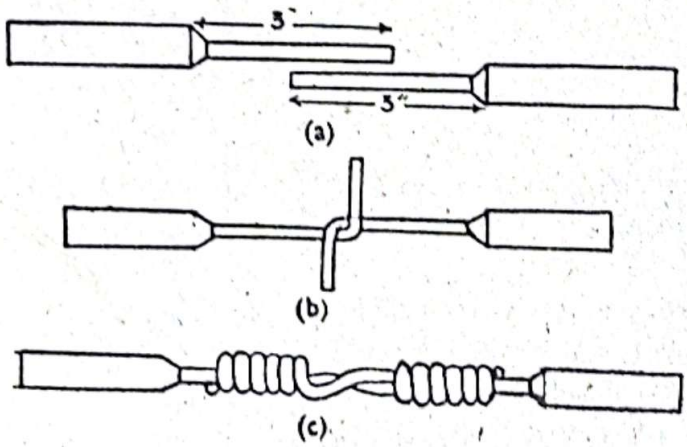


Fig. 2. Simple twist joint.

(2) *Western Union joint :—*

The Western Union joint is a modified form of the simple twist joint. The only differen between the Western Union joint and the simple twist joint is that a number of twists are taken at t centre instead of one. This joint is more efficient mechanically than the simple twist joint and capable of bearing considerable tensile strength.

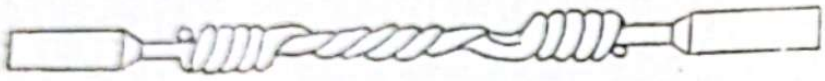
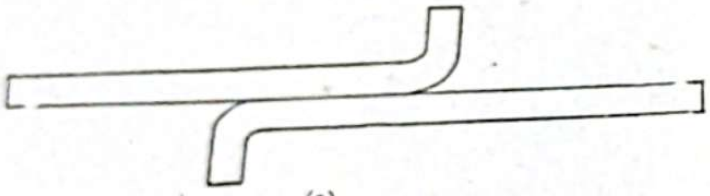


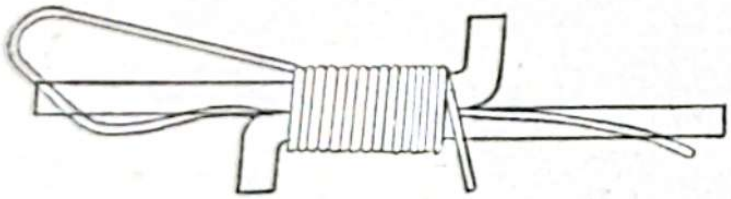
Fig. 3. Western Union joint.

(3) *Britania joint :—*

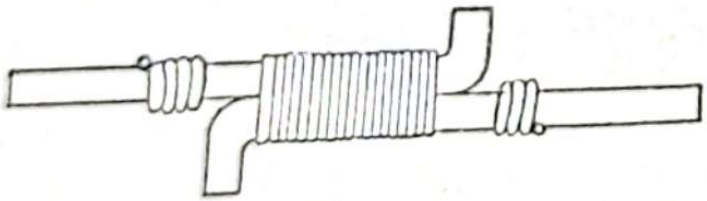
The Britania joint is used in overhead lines where tension is excessive. It is also used for insid as well as outside wiring, where single wire of less than No. 14 S.W.G. is used.



(a)



(b)



(c)

Fig. 4. Britania joint.

To prepare a Britania joint, clean the ends of the two wires thoroughly. Bend up at a right le one half inch of the wire as shown in Fig. 4 (a). Place the two wires in a vice together so that overlap about three inches. Wrap the joint with two tinned wires of the same metal as the s to be joined. Place the centre of the wrapping wires at the centre of the joint and wrap each rds the ends of the joint. After wrapping, force the free ends of the wrapping wires through rooves formed by the wrap and large wires. Make a few turns around the large wires at each f the joint with the portion of the wrapping wires left after pulling. The complete process is ated in Fig. 4.

*) *Scarf joint* :—

The scarf joint is used for large size single wires upto 12 S.W.G. where appearance and compactness are main considerations, and where the joint is not subjected to heavy tension. To make the scarf joint, clean the wires and taper about three inches at the ends to make a good fit with each other and which will look like a continuous wire when placed together. Tin the tapered ends. Wrap with 18 S.W.G. binding wire starting at the middle of the joint and wrapping towards the ends.

This method is often employed on 19, 37 and 61 strand cables, the inner group of strands being first soldered solid the scraped, and jointed. The soldering of the joint needs to be done carefully. If a great thickness of solder is left, the joint develops very high resistance, due to high specific resistance of solder, and much heat is developed at the joint to unsolder it.

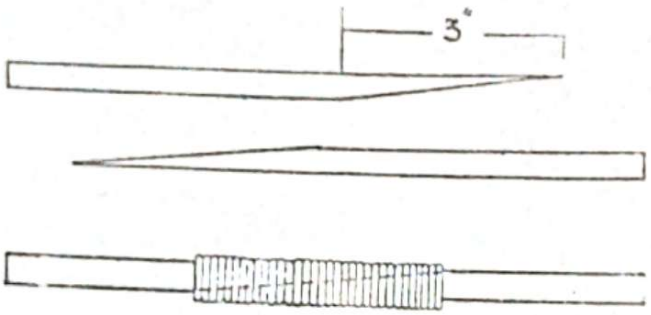


Fig. 5. Scarf Joint.

*) *Duplex joint* :—

A duplex joint is formed with a two core cable and is mostly used in conduit wiring where such cable is used. In preparation it is identical to two simple twist joints spaced so the joints do not come opposite to each other. This gives better insulation than when the joints are opposite one another.

Fig. 6. Duplex Joint.

*) *T-Joint and splice* :—

A plain T-joint of single conductor cables is most frequently used and is quickly made by removing $1\frac{1}{2}$ inch of insulation along the run wire at about 3 inches at the end of the T wire. The wires are crossed at about $\frac{1}{2}$ inch, and five to six turns of T wire are made around the run wire.

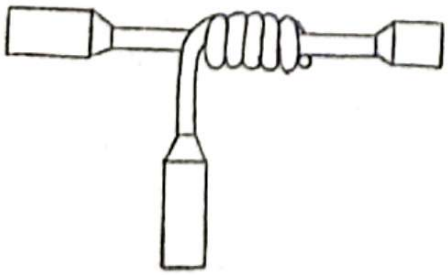


Fig. 7. Simple T Joint.

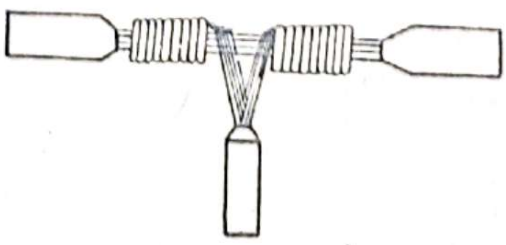


Fig. 8. T splice.

With stranded conductors the splices are made by twisting the T wire on both sides. F
example in a 70/0.64 T-splice, three wires are twisted on one side and four on the other of the run cabl
The two twists are made in opposite directions to give the splice strength.

(7) *Soldering* :—

The purpose of soldering joints and splices of electrical conductors is to make a connection wi
negligible resistance which will be permanent. When solder is applied, a joint is protected fro
oxidation and corrosion and is improved in mechanical strength.

The basic requirement of soldering is to have the surface clean and hot enough to melt the solde
To prevent oxidation of the surfaces, when they are heated, a flux of rosin is applied. Usually the ros
is contained in the core of the solder. An acid flux, or acid core solder, must never be used i
electrical work as corrosion will result. Solder should be applied to the joint and not to the solderin
iron itself. This means that the iron must be held on the joint long enough to melt the solde

Fig. 9. Correct soldering method.

If the solder is pasty, either the soldering iron is not hot enough or it is too small for the job. This
makes a "cold" or "rosin" joint which has a high resistance. An iron will impart maximum heat
when it is held with a flat side of the tip against the work and is properly tinned.

When the solder has been applied, the joint should be held absolutely still as the heat is removed
and the solder cools. Any slight vibration will produce crystallization and make a false joint. If this
happens the connection will have a grainy appearance instead of a bright finish. When the joint has cooled,
which can best be judged by a change in the lustre, it should be tested by pulling on the wires to make
sure they are solidly joined. Excess solder on a joint is messy. It may interfere with other connections,
and it does not show good workmanship.

Solder is made of lead and tin, and when properly used will actually form an alloy with such metal
s copper, brass, iron and tin pasted parts. Ordinary solder will not work with aluminium. With nickel
lated parts a non-corrosive soldering paste sometimes may be helpful.

are of soldering iron :

A new soldering iron must be tinned before it is used, that is, a coating of solder must cover the
to prevent oxidation and pitting, and also to permit a rapid flow of heat to the joint. To tin the

iron, heat it until it will melt solder and file the faces smooth. Immediately apply solder to the brightened copper until it is thoroughly " wet ". After use, when the iron becomes blackened and pitted, it must be retinned. Occasionally the tip should be wiped with a rough cloth or rubbed with steel wool to clean the face.

V. TAPING

After soldering, a joint or splice is insulated. This operation is rendered with an insulating tape. To insulate the bare joint it is wrapped first with $\frac{1}{2}$ or $\frac{3}{4}$ inch wide rubber tape spirally until this coating is equal to the thickness of the regular insulation. Then about two layers of $\frac{1}{2}$ inch or $\frac{3}{4}$ inch wide friction tape are coated over the rubber tape. In order to get good insulation the taping must be done with tension and each layer of tape must overlap the last.

EXERCISES IV

1. Describe the following operations :
   (a) Skinning.
   (b) Scraping.
   (c) Soldering.
   (d) Taping.
   What precautions will you use in each case ?

2. Describe with neat sketches the preparation of a simple twist joint. How does it differ from a western union joint ? Where is this joint used in electrical work ?

3. Describe the method of preparing a Britania Joint. Illustrate your answer with sketches.

4. What equipment, material and procedure will you use to make a scarf joint ? Under what conditions is this joint used ?

5. What is the difference between a joint and a splice ? Explain with neat sketches how will you make a duplex joint in 7/.029 V.I.R. cable. Where is this joint mostly used ?

6. What splice would you recommend to take a too off connection from 7/.036 cable ? How is the splice made ? Illustrate your answer with sketches.

7. A strong joint is needed for overhead service wires of an electrical installation. Which type of joint would yon recommend for the purpose and how will you proceed to prepare it ?

8. In soldering cable connections, certain precautions must be observed to prevent damage to the joint. Describe these precautions and the tools, methods and matarials to be used to ensure satisfactory results.

9. (a) What type of soldering fluxes are used in electrical work, and what type are prohibited ?
   (b) How will you prepare a new soldering iron for soldering work ?

10. What precautions you will take for :
    (i) good soldering.
    (ii) keeping the soldering iron in good condition.

CHAPTER V

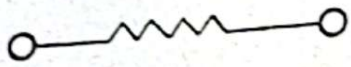
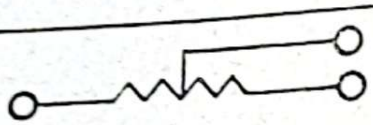
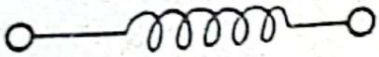
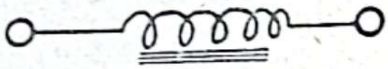
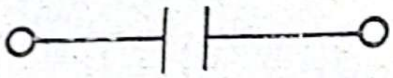
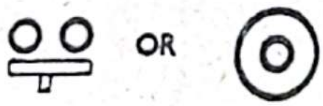
LAMP AND BELL CONTROL CIRCUITS

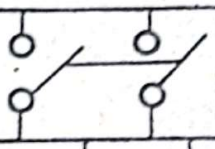
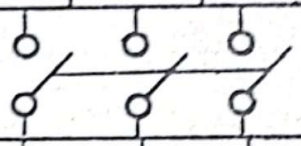
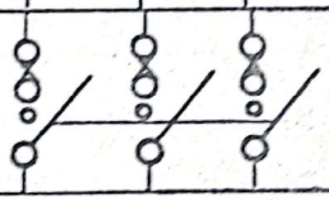
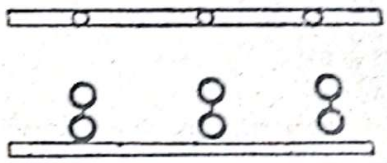
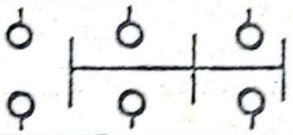
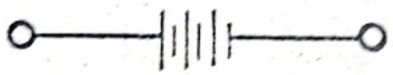
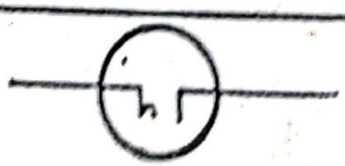
Various lamp and call bell control circuits have been developed for maximum convenience and economical use of electric light and bells. In this chapter the following circuits will be discussed :

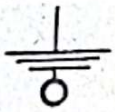
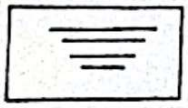
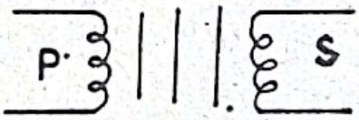
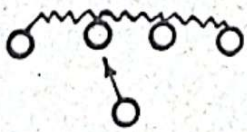
(1) Simple switch circuits.
(2) Two way switch circuits.
(3) Intermediate switch circuits.
(4) Master switch circuits.
(5) Marvel switch circuits.
(6) Fluorescent lamp circuits.
(7) Bell circuits.
(8) Bell and indicator circuits.

WIRING SYMBOLS

Circuits are illustrated by wiring diagrams. A wiring diagram is a functional drawing which traces the path of input voltage through an electric circuit and shows the functional relationship of component parts of the circuit to each other and to the circuit as a whole. The component parts are shown by symbols. A common set of symbols to designate various components used in wiring has been adopted. This facilitate reading and understanding wiring diagrams. The more common of these symbols used in wiring diagrams are given below.

Description	Symbol
Fixed Resistance	
Variable Resistance	
Inductance Choke	
Iron Core Inductance	
Capacitor	
Fuse	
Link	
One way Switch	
Two way Switch	
Intermediate Switch	
Push button Switch	
Marvel Switch	

Double pole Switch	
Triple pole Switch	
Fused Switch-for Example Triple pole Fused Switch	
Distribution fuse board	
Circuit breaker	
Battery	
Ammeter	
Voltmeter	
Energy meter	
Incandescent Lamp	
Fluorescent Lamp	
orescent Lamp Starter	

Earth Connection	
Water main Earth	
Test point for earth	
Earth plate	
Transformer	
Electric bell	
Bell Indicator N = No. of Ways	
Fan	
Fan Regulator	
Two pin Socket	
Three pin socket	
Surge Diverter	
Aerial	

I. SIMPLE SWITCH CIRCUITS :

Simple switch circuits are used to control one or more lamps from one single pole switch. Fig. 1 shows a circuit in which one lamp is controlled by one single pole switch. It may be noted that switches in all the circuits are placed on live wire though they can control the circuit when placed on neutral too. This is done to prevent accidents when the switch is "off".

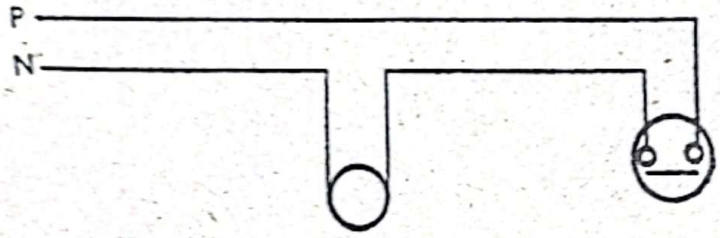


Fig. 1. One lamp controlled from one switch.

Fig. 2 shows a circuit in which two lamps are controlled in parallel by one single pole switch. The lamps may be installed either on the same fittings or different fittings.

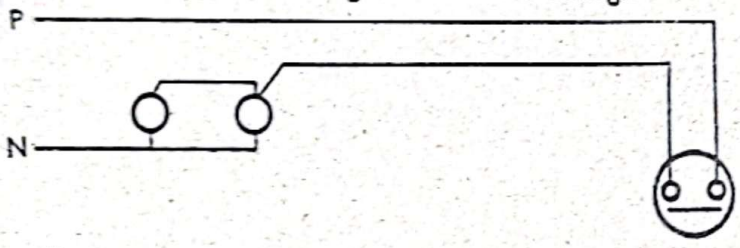


Fig. 2. Two lamps in parallel controlled from one switch.

The two lamps can also be controlled in series by one single pole switch. Fig. 3 shows the wiring diagram. When two or more lamps are connected in series, the sum of voltage drops at each lamp is the supply voltage. The decrease of pressure makes the lamps glow dim.

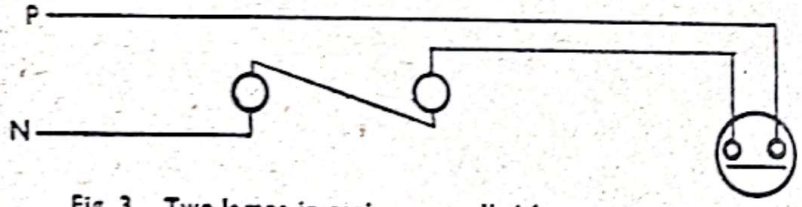


Fig. 3. Two lamps in series controlled from one switch.

In lighting circuits sometimes, a number of lamps are controlled by individual switches. Fig. 4 shows the control of two such lamps, and the possibility of extending the circuit to more lamps.

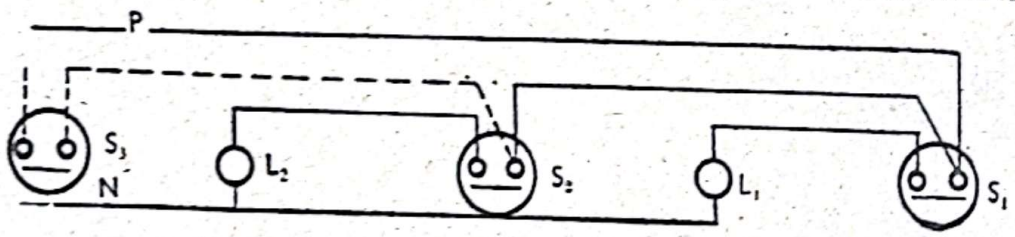


Fig. 4. Two lamps controlled by individual switches.

It may be noted that the phase conductor from switch S_1 is looped to switch S_2 directly, and if a third lamp is also to be controlled by a switch S_3 individually, the phase from switch S_2 should be looped the same way.

II. TWO WAY SWITCH CIRCUITS :

These circuits are used to control, one or more lamps from two positions. Some of the situations where the use of such circuits provide much convenience are (i) a staircase (ii), room with doors and (iii) in corridors.

Fig. 5 shows control of a lamp from two different positions. A two way switch S_1 at a point A and a similar switch S_2 at another point B are used to control lamp L.

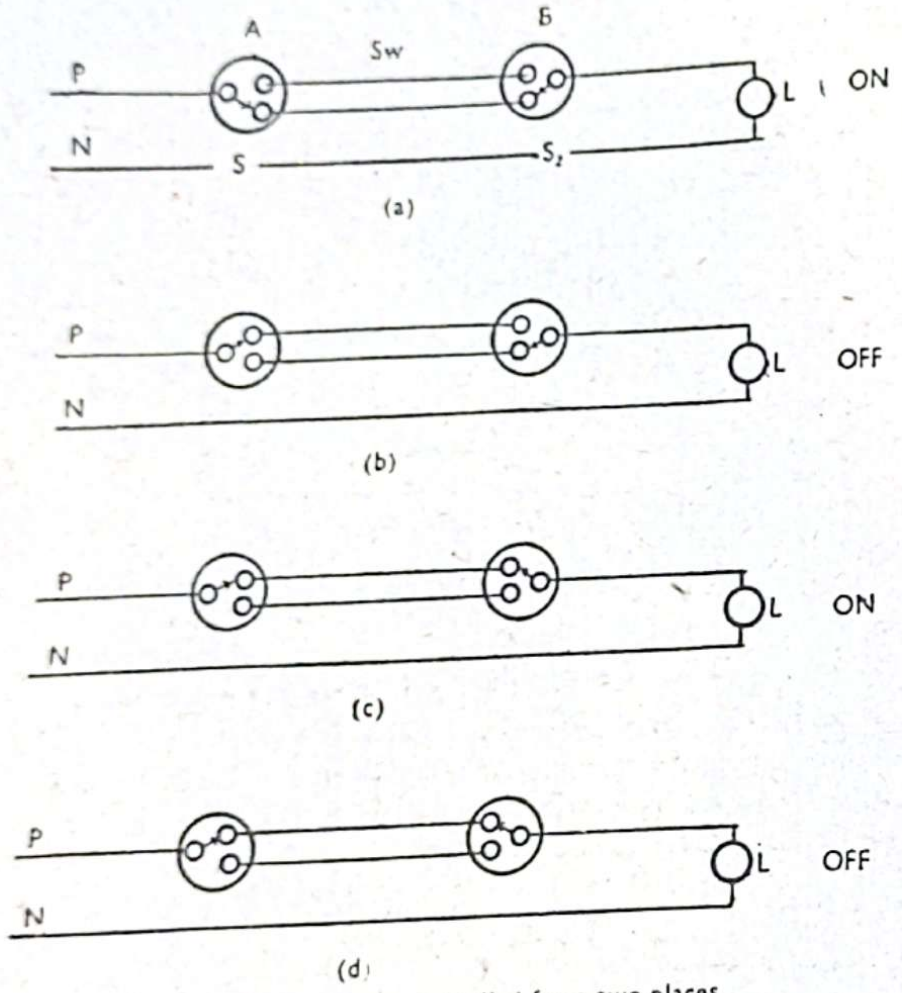


Fig. 5. One lamp controlled from two places.

S.W. are strapping wires between the two switches. The figure shows the four different conditions of the circuits. When the two way switches are in conditions shown in figure 5 (a) and 5 (c) the circuit is complete and the lamp glows. In the other two positions the lamp circuit is not completed, and the lamp remains dark.

Fig. 6 illustrates a series of two way circuits suitable for corridors.

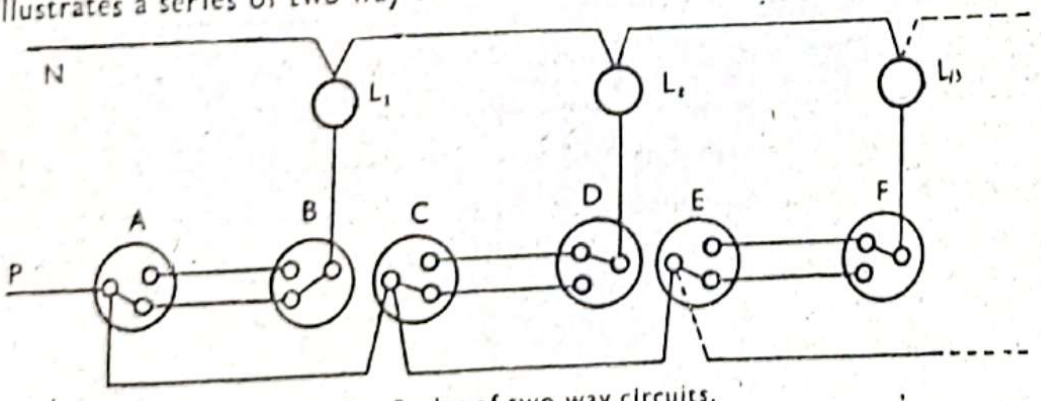


Fig. 6. Series of two way circuits.

The lamps and switches are fitted in a corridor the lamps L_1 may be turned on at A and off at B. Similarly L_2 can be turned on at C and off at D, etc.

III. INTERMEDIATE SWITCH CIRCUITS :

The use of an intermediate switch circuit with two way switches enables a wireman to control lamps from more than two positions. The use of intermediate switch circuits is extensively made in the following situations :

(1) In a house or building of several floors to switch off the staircase lights from either ground, top, or intermediate floors or landings.

(2) In a large room with three or four doors a lamp for general illumination may be controlled from any door or other desirable position.

(3) In a bed room where control of the lamps is desired from the door, bed, dressing table, and dressing room.

(4) In a long corridor with a number of doors opening into it, where it is desired to control lamps (in parallel) from either end or any intermediate door.

An intermediate switch has four terminals indicated by 1, 2, 3, and 4 to which strapping wires are connected. The moving contacts d_1 and d_2 make contacts with the terminals in two positions for two types of intermediate switches manufactured are shown in Fig. 7.

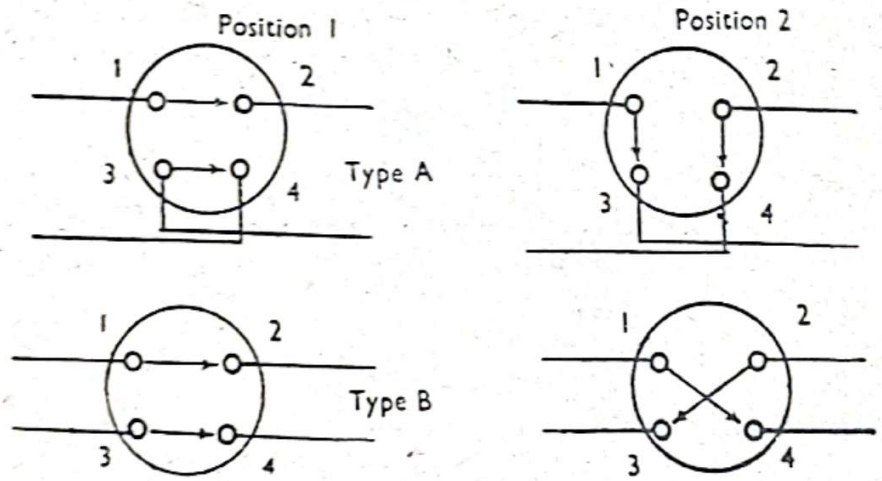
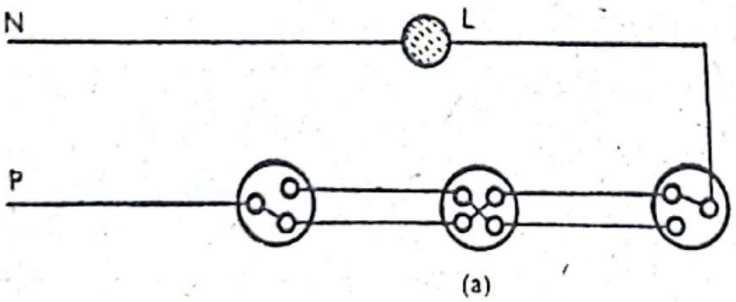


Fig. 7. Two position of intermediate switches.

Fig. 8 (a, b and c) show the wiring of intermediate switch circuits. In these circuits one, two and three intermediate switches have been introduced in a circuit with two "two way" switches, allowing control of a lamp L from three, four and five positions. Thus by introducing a number of intermediate switches control of a lamp from any number of positions can be obtained.



(a)

Fig. 8.

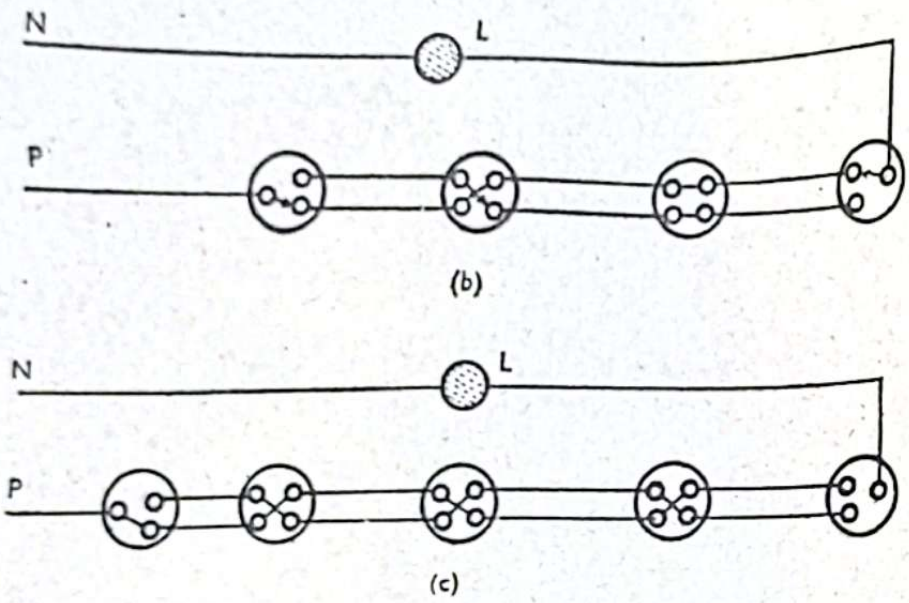


Fig. 8. Two way and intermediate switching.

IV. MASTER SWITCH CIRCUITS :

The introduction of a master switch in a circuit restricts the control of other switches when it is "ON". The application of a master switch control circuit is made to illuminate lights for general illumination of building, or particular lights of building at the will of the master of the house. Thus a master switch may be installed in the bedroom.

Fig. 9 shows how a master switch may be introduced.

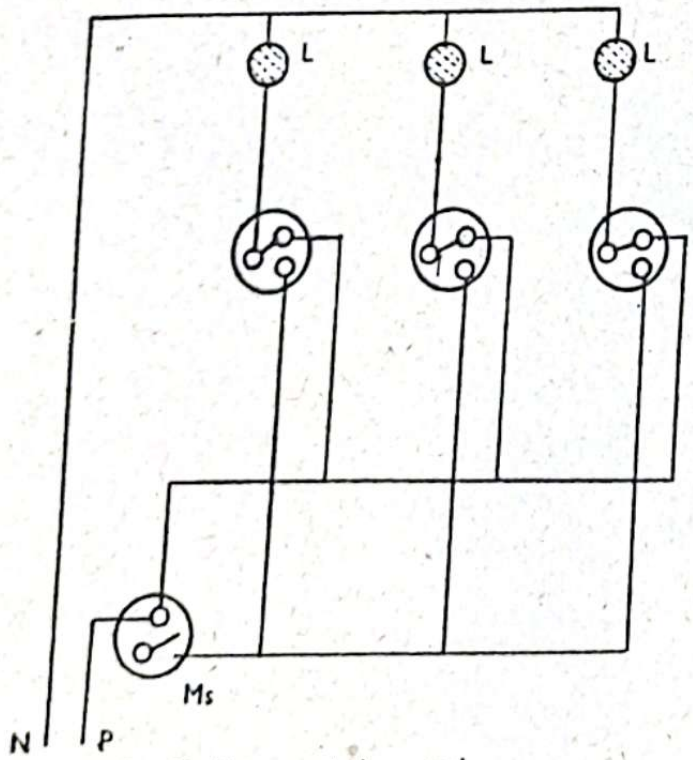


Fig. 9. Master switch control.

It can be noted that when the master switch is "ON" no switch can extinguish the lamps. When the master switch is "OFF" all other switches are operative and the lamps can be controlled by each individually.

V. MARVEL SWITCH CIRCUITS :

A marvel switch of the tumbler type has five terminals and is capable of making three interconnections in three different positions of the lever. Fig. 10 shows the interconnections of a marvel switch when the lever is (i) up (ii) intermediate and (iii) down.

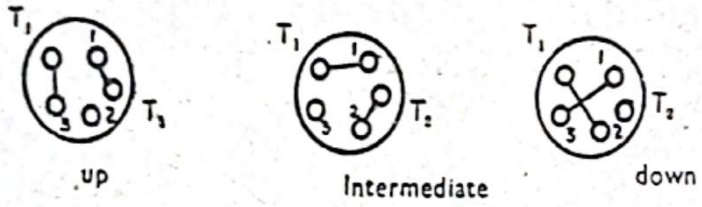


Fig. 10. Inter connections of marvel switches.

A single marvel switch can be used to control a lamp at each at the interconnections. Fig. 11 shows it is used in a circuit where two lamps are employed to give "full" or "dim" light.

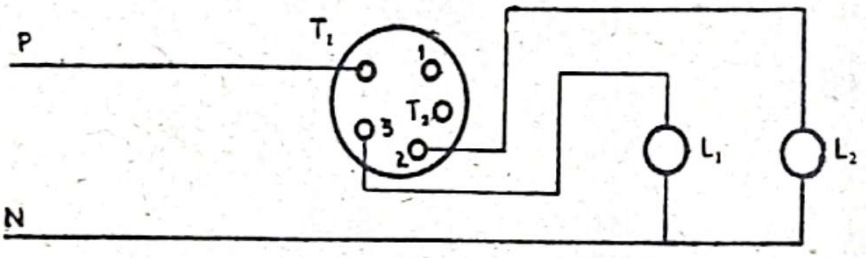


Fig. 11. Control of two lamps by marvel switch.

When the lever is up the lamp L_1 glows, when it is down L_2 glows, while at the intermediate position neither of the lamps glow. This circuit is useful for hospitals, bedrooms, ship cabins and other such places where during the early hours of night high illumination is required and during late hours dim light is needed.

Two marvel switches can also be coupled together to two lamps, so that either may be lighted from either switch. Fig. 12 shows the circuit for such a connection.

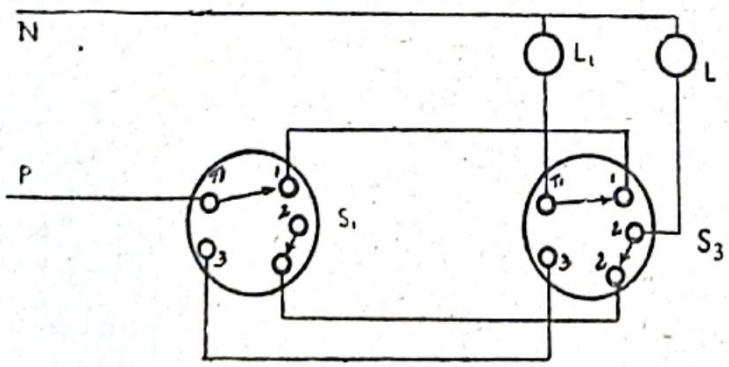
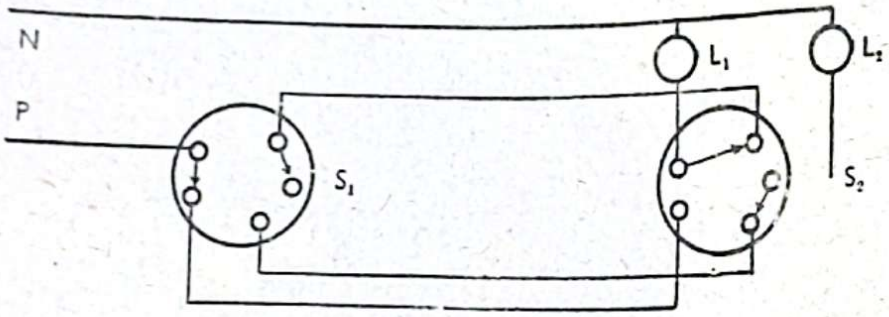


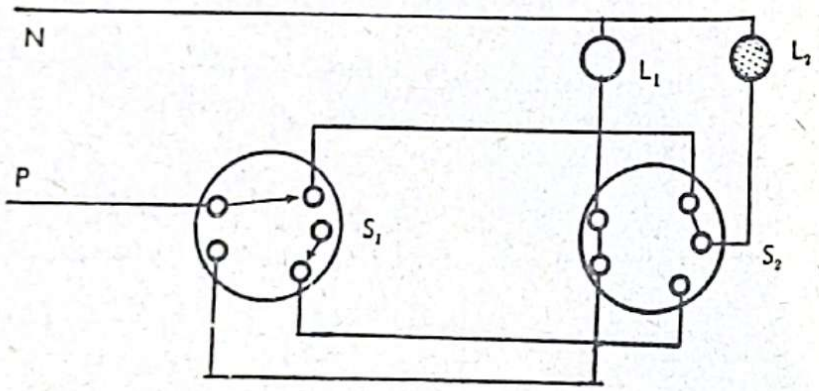
Fig. 12. Two coupled marvels switches connected to two lamps, so that either lamp may be lighted from either switch.

There are nine different relative positions of the two switches. The positions in which each of the lamps will glow, and when current to both the lamps is off can be understood with the help of

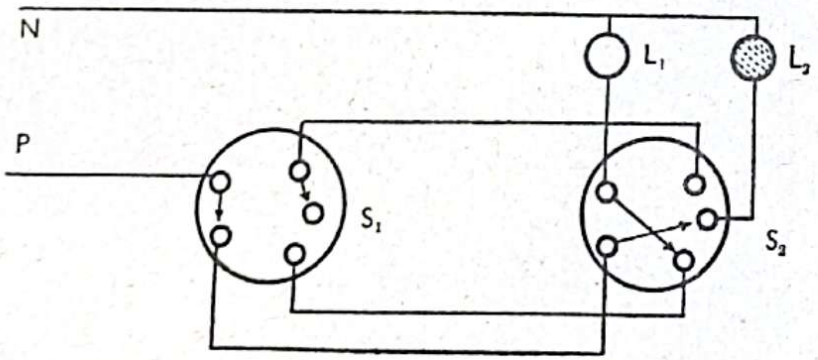
Fig. 13 given below.



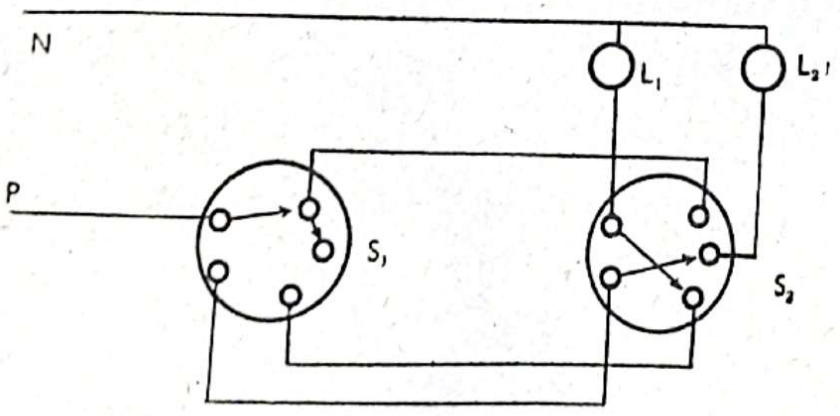
(1) S_1 up, S_2 central, L_1 L_2 dark



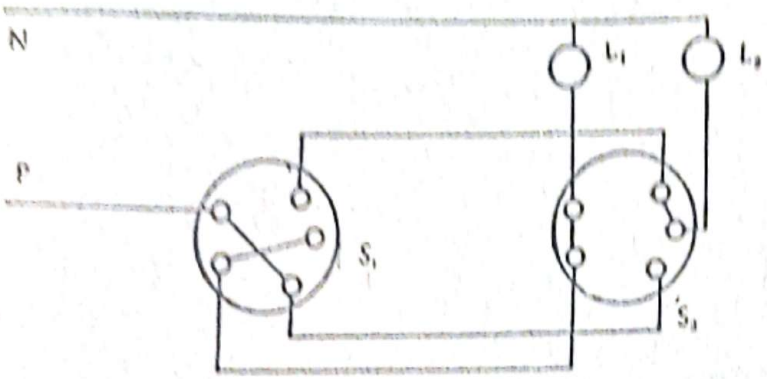
(2) S_1 up, S_2 down, L_2 "on"



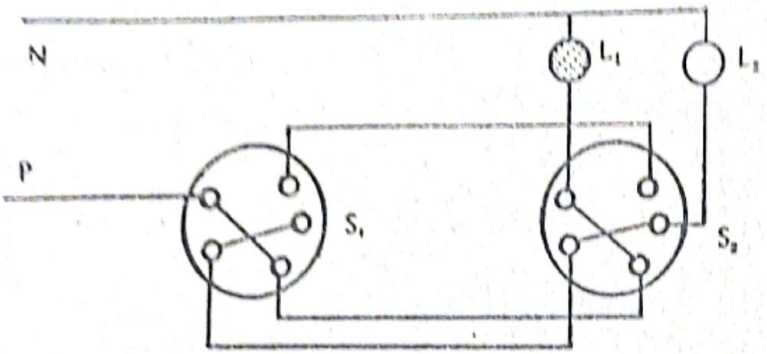
(3) S_1 central S_2 down down L_1L_1 dark



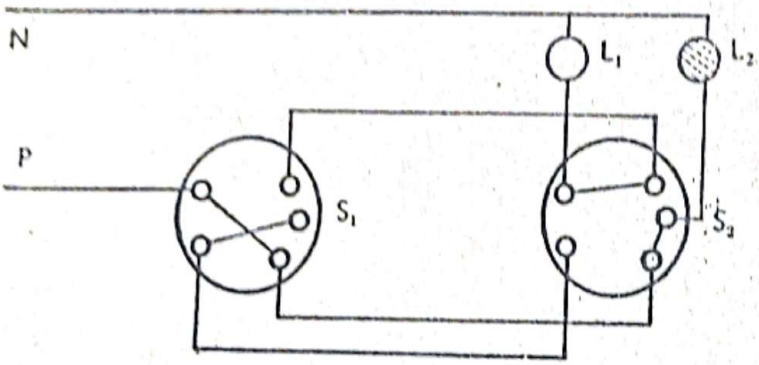
(4) S_1S_2 central, L_1 on



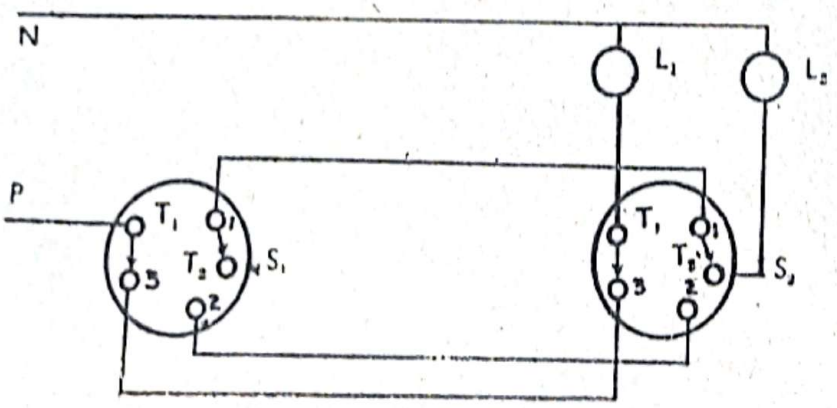
(5) S_1 Central, S_2 up, L_2 on



(6) S_1 down S_2 up, L_1L_2 dark



(7) S_1 down S_2 central L_2 "on"



(8) S_1S_2 down, L_1 "on"

Fig. 13. Actions of two coupled marvel switches.

VI. FLUORESCENT LAMP CIRCUITS :

Fluorescent lamp circuits can be broadly divided into two types (i) hot cathode lamp circuits and (ii) cold cathode lamp circuits. Hot cathode type fluorescent tubes operate a low voltage. Cold cathode type tubes need high voltage, and a step-up transformer is needed to supply it. In this book, study is limited to simple hot cathode fluorescent circuits.

The main parts of a simple hot cathode lamp circuit as shown in Fig. 14 and 15 are (1) fluorescent lamp (2) choke (3) starter and (4) condenser for power factor improvement.

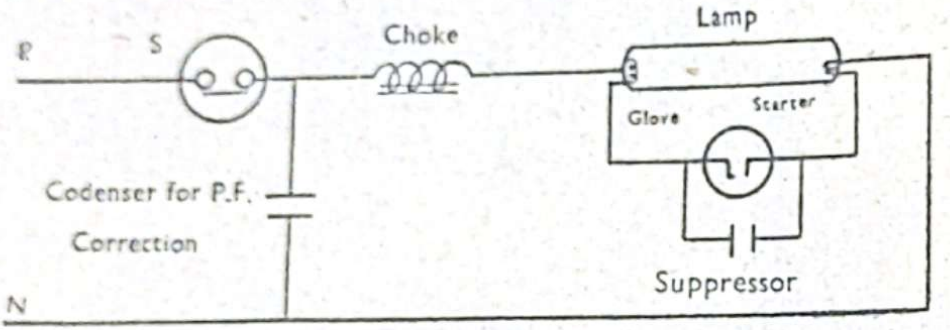


Fig. 14. Fluorescent lamp circuit with glow starter.

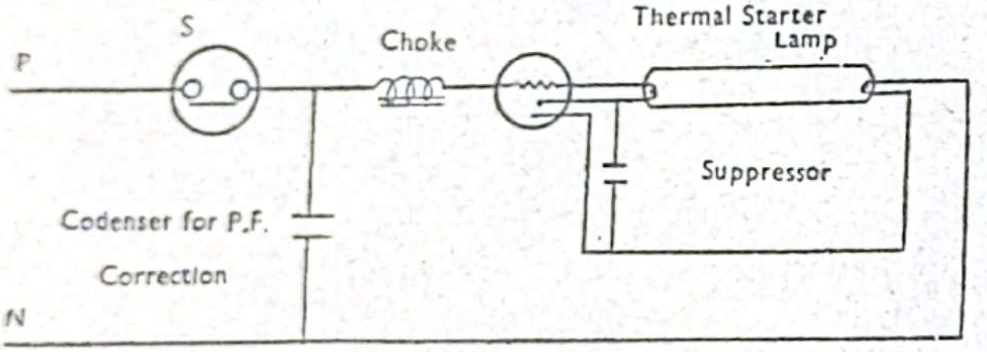


Fig. 15. Fluorescent lamp circuit with thermal starter.

FLOURESCENT LAMP

A fluorescent lamp consists of a glass tube fitted with electrodes at each end and coated internally with fluorescent powder the composition of which determines the colour of the light given out. The fluorescent powder is activated by the ultra-violet rays generated by the passage of an electric current between the lamp electrodes within the lamp.

Fluorescent tubes can be obtained in a variety of lengths with illumination in a variety of colours. Advantages in using fluorescent lamps are that illumination is many times more than an incandescent lamps of the same wattage and the glare is much less. The disadvantage of fluorescent lighting is the stroboscopic effect caused by the gas glowing and extinguishing with every cycle of alternating current. Thus a fluorescent lamp fliker occurs 100 times per second on a 50 cycle supply.

(2) Choke :

A choke is a high inductance which is connected in series with the fluorescent lamp electrodes. The high inductance is obtained by giving a number of turns of enamelled copper wire over an iron core built up from sheet steel stampings.

A choke connected in series with the fluorescent tube has two purposes. At the time of starting it sends high voltage pulse to help initiate an arc between the electrodes, and after the arc is ignited it drops the desired voltage to a value equal to the product of the lamp current and its impedance.

3) *Starter :*

A starter helps in initiating the arc between the electrodes in the fluorescent tube, by closing and opening its contacts, until full current flows through it. Two types of starters are commonly used with fluorescent tube circuits. The terminal type of starter consists of a heater coil to operate a bi-metal electrode. Its contacts are closed before the current to the lamp is switched on. The starter contacts are held open all the time the tube is in operation by the current in its heater coil which is in series with the tube.

The other type of starter is the glow type. This is a small discharge tube of the negative, glow type, the electrodes forming the switch contacts. In this case, when the current is switched on, the starter contacts are open. A glow starts between these contacts which heats them, and cause the contacts close. As a consequence, the current passing through the tube filaments is increased, causing them to become bright red hot. The bi-metal strip of the starter cools down and after a few seconds the starter contacts open, causing a high voltage to be induced across the tube, which then starts to function.

Both types of starters will be found in practice, but the glow type of starter has certain advantages over the thermal type. The main advantage is that the glow type requires only a two-wire connection, whereas the thermal type requires four wires.

(4) *Condenser for power factor improvement :*

The power factor of a fluorescent lamp circuit is low due to high inductance. A low power factor means that the circuit current will be high, which in its turn will require connecting wires of greater cross section. In order to decrease the circuit current a condenser is usually connected across the circuit. The value of the condenser used is such that it improves the power factor to 0.85.

VII. BELL CIRCUITS

An electric bell circuit comprises of an electric bell, a push switch, connecting cables, and a source of electric supply. Electric bells of 3, 6 and 12 volts ratings, for direct and alternating current circuits, are mostly available, but 230 volt A.C. bells are also now found in the market.

When low voltage A.C. bells are used on 230 A.C. supply circuits, a bell transformer is required to step down the voltage. The bell transformer must be double-wound and one pole of the secondary must be earthed. Further, the transformer primary circuit must contain a switch when it is connected to a subcircuit supplying other apparatus. The transformer secondary circuit should be fused to protect it under faulty conditions.

Overseas bell wires are usually 1/.036 rubber or P.V.C. insulated. When rubber is used, one or two layers of cotton is provided for mechanical protection. The wires are coated in a variety of colours to assist in identification. In such a wiring system, all wires leading from the positive pole of a battery to any push switch are of plain bright colour such as white, yellow and red. Plain dark colour wires such as blue and black are used for the wires leading to the negative pole of the battery, and all the wires running between apparatus (such as push switch to bell are indicator) are doubly coloured.

In Pakistan 1/.044 weather proof, V.I.R. lead sheathed or C.T.S. wires are usually used. When wiring is done on teak wood battens, weather proof, lead sheath or C.T.S. wires are mostly installed but V.I.R. wire is used in conduit and casing and capping installations. For temporary installations the use of weather proof cable on cleats has also been made.

For circuits using low voltage it is not essential to have high standard of insulation, but it must be ensured that robust wires are used, especially for concealed circuits. Moreover the contacts and screw connections should be clean and tight because even the smallest contact resistance in the circuit will cause the current to fail. The Electricity Rules of 1837 require that bell wiring and equipment must be completely separated from the supply circuits unless insulated for the supply voltages.

In Fig. 16 a simple battery bell circuit is shown, and in Fig. 17 shows a bell circuit fed from a bell transformer. The circuits are self explanatory. It can be noticed that pressing the push switch will complete the circuit, and ring the bell.

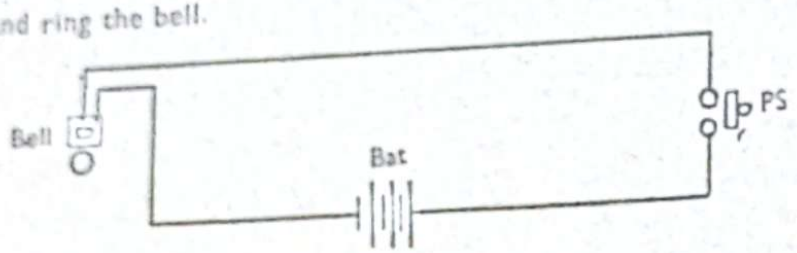


Fig. 16. Battery operated bell circuit.

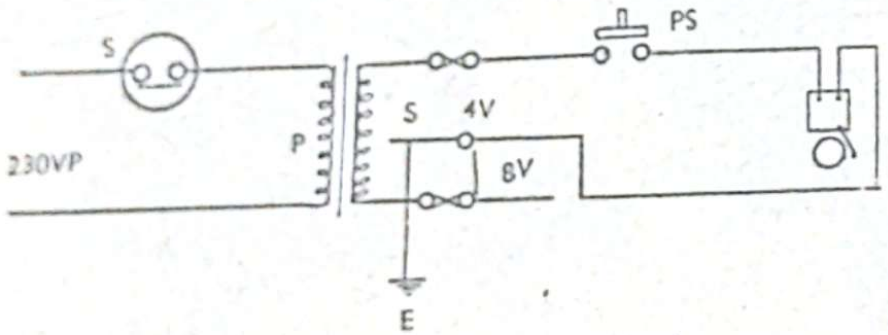


Fig. 17. Transformer operated bell circuit.

A number of bells can be controlled from one push switch. To accomplish this the bells are connected in parallel. A bell-transformer or a battery can be used as a source of electric supply. Fig. 18 shows such a connection. An earth connection may be used for the negative wire. This system may be used for fire alaram signalling where many departments or places are to be informed.

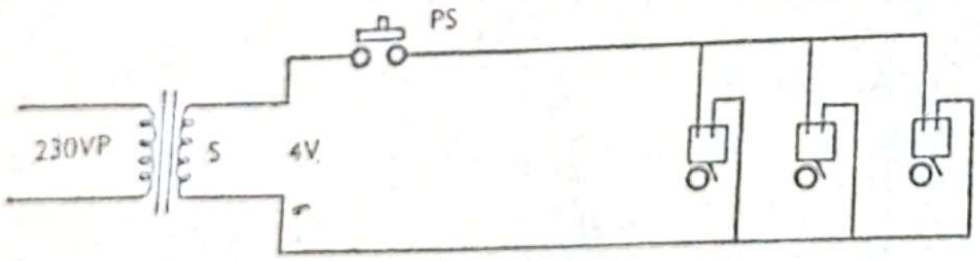


Fig. 18. A number of bells operated by one push switch.

VIII. BELL AND INDICATOR CIRCUITS

In many places like large restaurants, hotels, hostels, and bedrooms, where an attendant is to be called from many places, push switches are installed in rooms controlling a bell at the attendant's place. In order to tell the attendant from which room the call has been given, bell-indicators are connected with the bell. In pendulum type bell-indicators electromagnets are connected in series with the bell. Each bell circuit has its own electromagnet and corresponding indicator position. On pressing any particular switch from a room, the core of electromagnet is magnetised and attracts the suspended armature, which

carries an indicator such as a star. When the current is stopped the pendulum is released and swings to and from behind the particular hole showing the room from where the call has been booked.

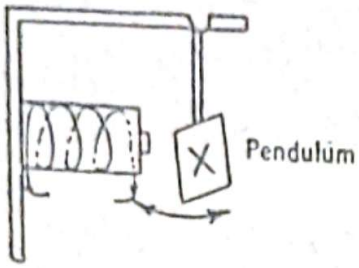


Fig. 19. Pendulum Indicator.

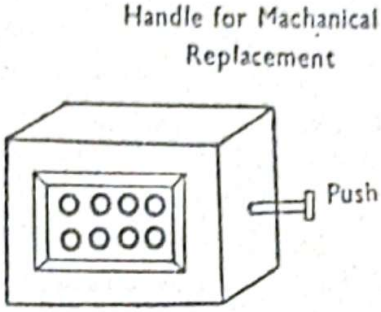


Fig. 20. Flag drop mechanical replacement indicator.

The pendulum type indicators are quite satisfactory for domestic installations where calls are few and are dealt by one attendant. In large installations such as hotels and hostels, some method of recording the signal in the absence of the attendant is also required. Flag drop mechanical replacement indicators are suitable for these places. In such indicators a flag is dropped by an electromagnet in series with the bell when call is made. The flag remains exposed until the replacement rod at the side of the case is depressed. In Fig. 21 is shown a bell with a bell indicator. The indicator may be either pendulum or mechanical replacement type.

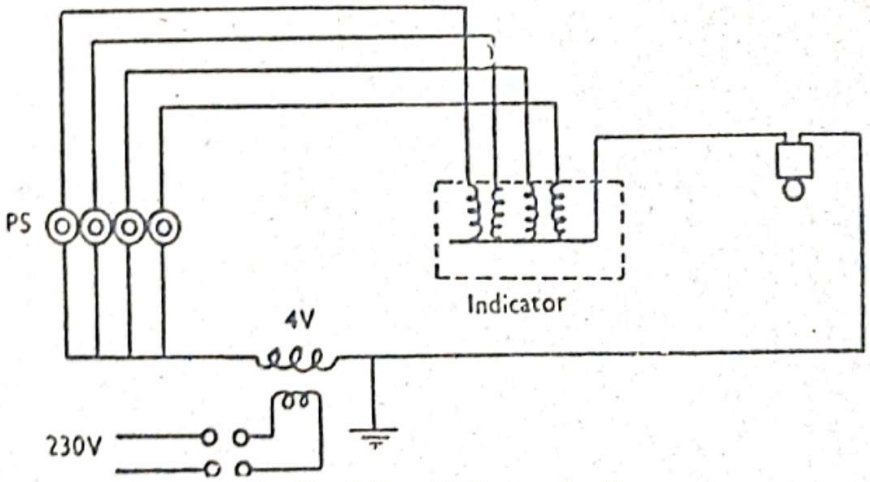


Fig. 21. Bell and indicator circuit.

When a push switch is pressed, the circuit is completed through the bell indicator and bell. The indicator shows the push position and the bell starts ringing to alarm the attendant.

EXERCISES V

1. Give the wiring symbols for the following :
   (i) push switch.
   (ii) three pin socket outlet.
   (iii) intermediate switch.
   (iv) marvel switch.
   (v) 6-way bell indicator.
   (vi) fluorescent lamp starter.
   (vii) bell transformer.

2. In a two storied domestic installation a stair case lamp at the first landing was controlled from two places. With the addition of one more story it was deemed essential that one more lamp controlled from second and fourth landing be installed. With neat sketch, draw the wiring diagram of the complete stair case circuit and make a list of additional material required.

3. Draw circuit diagrams for the following :
   (a) One lamp controlled by three switches, each switch providing independent control of the lamp.
   (b) A bell operated from six push switches.
   (c) A switch start fluorescent lamp.
   (d) Two lamps controlled by a marvel switch.

4. Explain with neat sketches the working of a master switch circuit. What are its advantages ?

5. Draw a circuit diagram of a hot-cathode fluorescent lamp with inductive ballast and starter switch control. Describe the operation of the circuit. What is meant by power factor and why is it necessary to improve it in this circuit ?

6. Draw circuit diagrams of the following :
   (1) A bell system comprised of three push switches, one three way indicator, one bell and a bell transformer.
   (2) One lamp controlled from two places.

7. What are the different types of bell indicators, and where they are used ? Explain with a neat diagram the working of pendulum indicator.

8. Make a diagram of a circuit for a simple fire alarm system in a three story building with one push switch on each floor controlling three common bells connected in parallel and installed one on each floor. The power to the system is delivered by a bell transformer.

CHAPTER VI

POWER SUPPLY SYSTEMS

Many power supply distribution systems are in use depending upon the nature of electric supply generated and their economic feasibility of distribution. Those mostly used are :

(1) Two wire D.C. system.
(2) Three wire D.C. system.
(3) Single phase A.C. system.
(4) Star connected system.
(5) Delta connected system.
(6) Three phase four wire system.

TWO WIRE D.C. SYSTEM

The two wire D.C. system contains two conductors one of which is positive and the other negative. The conductors are insulated throughout, and the load is connected between the positive and negative conductors,

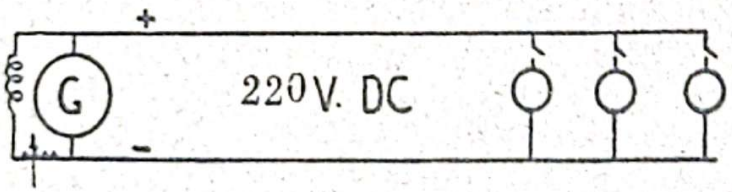


Fig. 1. Two wire D.C. distribution.

The disadvantages of this system of distribution is that only one value of voltage is available, and ts cost is high.

'HREE WIRE D.C. SYSTEM

The system contains three wires, two outer and one neutral which is half the cross section of the uters. Two voltages are made available by this system. The medium voltage is 220V between the ıter wires and neutral may be used for domestic purpose while 440V may be supplied for heavier dustrial load.

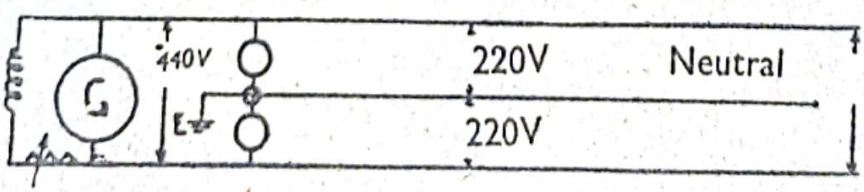


Fig. 2. Three wire D.C. distribution.

In this system a 440V D.C. generator is connected across the outer wires at the generating station. A balancer set is also connected in parallel to the generator. The balancer set consists of two 220 volts D.C. machines in series and mechanically connected, either of which may act as a generator or motor depending upon the balance of the load. The neutral wire from the balancer set is earthed.

In a three wire D.C. system the function of the balancer is to keep the potential difference between the outer wires and the neutral approximately the same under all conditions of load.

SINGLE PHASE A.C. SYSTEM :

A single phase system can either be taken from a single phase alternator or a three phase alternator which is star connected, and the star point is earthed. This system it used for domestic power supply up to 12 KW but is avoided for bigger supply in favour of three phase four wire system.

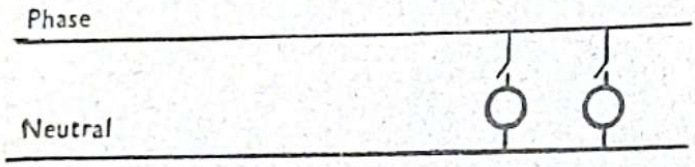


Fig. 3. Single phase A.C. system.

STAR CONNECTED SYSTEM :

In a star connected system each winding of an alternator or a distribution transformer are connected to a common point. Voltages between the wires, called line voltage (V_l), are 1.732 times the voltages in the windings (V_{pL}). This system is not economical for distribution of electric power, but is widely used for transmission of power over long distances.

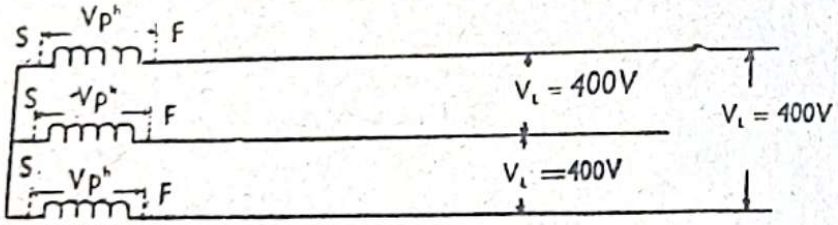


Fig. 5. Three phase star system.

DELTA CONNECTED SYLTEM

A delta connection is obtained when the three windings of an alternator or a transformer are connected, joining the start of one winding with the finish of the other.

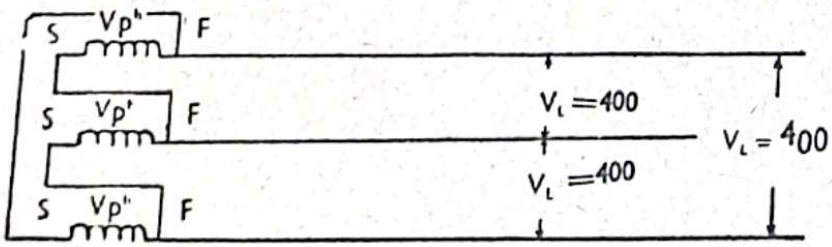
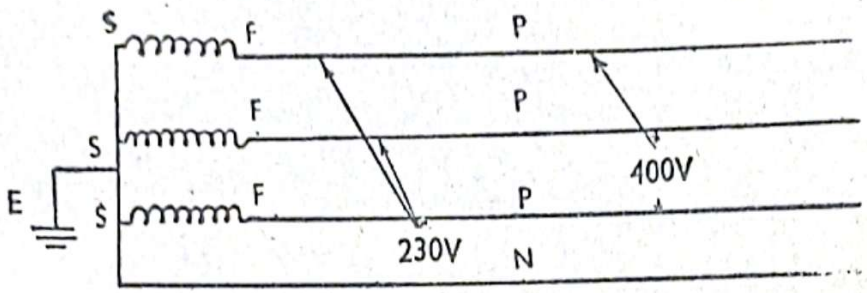


Fig. 5. Three phase delta system.

The phase voltage in the system is equal to the line voltage but the line current is 1.732 times ıe phase current.

THREE PHASE FOUR WIRE SYSTEM :

This system is similar to the star connection, the only difference being that the neutral point s earthed and a fourth wire called neutral is drawn from there.



Fig, 6. Three phase 4 wire distribution

The voltages between the phase conductors is the same as in the star connection i.e., 400V, but between the phase and neutral is 1/1.732 times or about 230V. Two voltages are thus available in in this system, It is widely used for distribution of alternating current power in Pakistan since at one end it can feed both domestic and industrial consumers with 230V and 400V, respectively, and on the other hand it is the most economical since the amount of copper used therein is a minimum.

TYPES OF PRESSURES :

The Electricity Rules 1937 classify different electrical pressures as follows :

(1) Low pressure	upto 250V
(2) Medium pressure	251 volts to 650 volts
(3) High pressure	above 650 volts.

For domestic installations low pressures upto 250 volts are mostly used, and medium pressures (sometimes along with low pressures) are used for industrial purposes. High pressures are used for primary distribution and transmission purposes.

VARIATION OF VOLTAGE AND FREQUENCY :

It is impracticable for supply authorities to maintain constant voltage and frequency at the consumers premises at all times. The variation of voltage is mostly due to the voltage drop in the distribution lines with the variation of load. The variation in frequency is caused due to the change in speed of the prime mover. According to the Electricity Rules 1937, Chapter IV, Art 28. supply authorities are permitted to vary electric supply voltage by five percent in case of low 250V and medium pressure 650V. The frequency according to Art. 22 can be varied upto 4% of the declared frequency at the consumers premises.

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EXERCISES VI

1. (a) Give the advantages of a three wire D.C. distribution system over a two wire D.C. distribution system.
   (b) The electric pressure between the outers of the three wires of a distribution is 410 volts. What will be the pressure between an outer and the neutral.

2. What are balancers and what is their purpose in a three wire D.C. system. Where are the balancers installed ?

3. What is the difference between a star and a delta connection ? (a) Why is electricity transmitted over long distances in a star system, and (b) why is it not used for distribution to domestic installations ?

4. Give the phase to neutral voltages delivered from a three-phase fourwire system in which the voltage between phases is
   (i) 415 V and (ii) 380 V.

5. Indicate by diagram the position of main fuses in
   (i) Three phase four wire supply,
   (ii) D.C. two wire (unearthed) supply,
   (iii) Two phase three wire supply, middle wire earthed,
   (vi) A.C. single phase supply.

CHAPTER VII

WIRING THE HOME

The type of service connection required by a consumer depends upon the load of electrical -liances he intends to use and the tariff offered by the electric supply company. In Pakistan light d power loads are charged at different rates. The tariff offered by WAPDA for light and fan load being paisas per B.O.T. unit, and that for power, 15 paisas per B.O.T. unit.

In domestic installations of upto 12 KW using light and power loads only, single phase 230 volts pply is brought in. In bigger installations a three phase 400 volts connection is installed. In ter to meter light and power, separate energy meters, main switches and distribution fuse rds are installed as shown in the Fig. 1. All the circuits for power and light from distribution r boards are run separately and are distinguishable from one another. It is a good practice to k all meters, main switches, and distribution fuse boards with a letter or number or both. The prefix " for lighting and "P" for power may be used.

Whether or not electricity can be used to its fullest extent depends upon the adequacy of the ring. This can be achieved if the following points are taken into consideration :

(a) The conductors installed must be of a sufficient size to carry safely the maximum load current. calculating the maximum load currents for service line and sub-main cable that supplies two or re distribution boards from main distribution boards. Diversity factor may be applied except the case of final subcircuits. When long runs are to be made a larger size of cable may be essary to avoid excessive voltage drop. The voltage drop from the incoming supply to any point the installation should not exceed 1 + 2% of the declared voltage supply. Thus for a supply of volts, the allowable voltage drop is 6 volts.

(b) All circuits must be adequately protected against excess currents.

(c) Every final sub-circuit shall be connected to a separate way on a distribution board.

(d) Any number of points may be supplied by a final sub-circuit provided the total possible does not exceed 15 amps. (Note : good planning demands intelligent segregation of points, rticularly for domestic installations where one or two sub-circuits should be reserved for lighting).

(e) A final sub-circuit of rating exceeding 15 amps shall supply only one point except where d plugs and socket outlets are used and the total rating of the circuit does not exceed 30 amps.

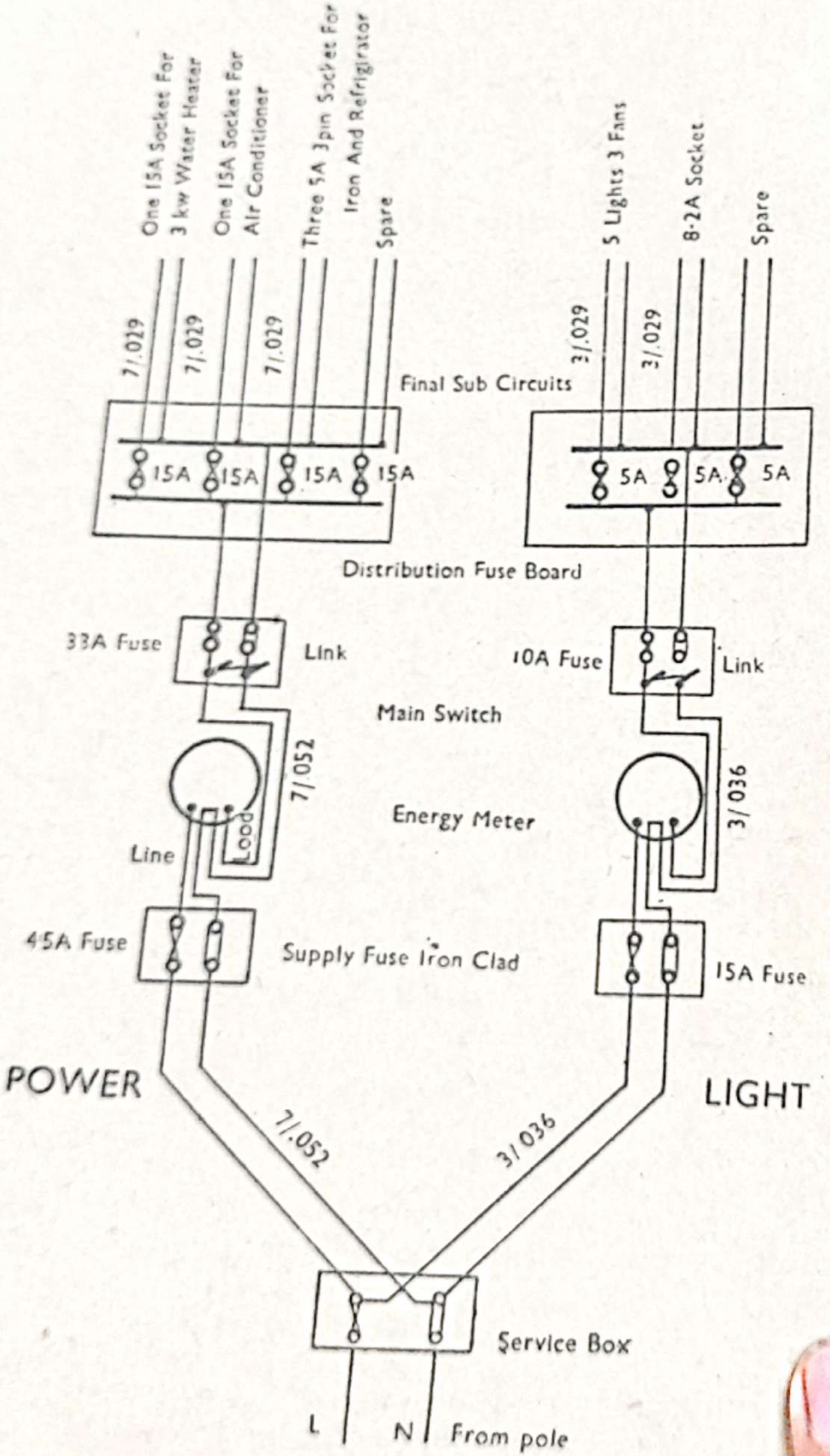

Fig. 1. Typical Wiring Detail of a Domestic Installation

(f) In calculating current requirements for final sub-circuits, the following allowances should be made :—

Each 15-amp socket-outlet requires 15 amps.

Each 5-amps socket-outlet requires 5 amps.

Each 2-amp socket-outlet requires ½ amp at least.

Each lamp-holder requires 100 W, at least

Each ceiling fan requires 100 W.

(g) In calculating the number of fluorescent lamps that can be installed to a final sub-circuit take twice the rating of each of the fluorescent lamps.

EXAMPLE 1.

Find the number of points of incandescent lamps and ceiling fans that can be installed on 3/.029 V.I.R. Cable in a place where maximum shade temperature is 113°F. The maximum cables grouped together may be taken six Assume declared supply pressure 230 V.

From Appendix III table I the current rating of 3/.029
Cable = 10 amp.
and (1) rating factor at 113°F = .47
(2) grouping factor for six = .7

The maximum allowable current for the cable under this situation
= current rating × rating factor × grouping factor.
= 10 × .47 × .7 = 3.3 amp.
Maximum power supplied = 3.3 × 230
= 750 watts.

No. of light and fan points $= \frac{750}{100}$
= 7.5 say

EXAMPLE 2.

In the above example find the number of 40 watts fluorescent lights that can be installed instead of incandescent lamps and fans.

Maximum power supplied by 3/.029 Cables = 750 watts.
Wattage of one point for estimation = 2 × 40
= 80 watts.

$\therefore$ No. of points $= \frac{750}{80}$ = 9.45 say 9 points.

From these examples it can be noticed that seven to eight light or fan point per final sub-circuit is a good practice.

DEFINITIONS OF TERMS USED

SERVICE LINE

The line which connects the distributors along the roads to the fuse cut outs of the consumers installation is called service line may be under ground or over head. The electricity Rules 1937 require

that all service lines to consumer's premises either underground or over head should not be access without a ladder or other special appliances, and shall be so insulated and protected as to be secure un all ordinary conditions against electrical mechanical, chemical or other injury to the insulation and against access of moisture.

SUBMAIN CABLE

The cables feeding distribution boards from main distribution board are called submain cables.

POINT

The end of fixed wiring feeding a socket out let celling fan or lamp holder is called a point.

FINAL SUB CIRCUIT

A final subcircuit is the last circuit which is drawn from a distribution board or switch fuse feed one or more points without a distribution fuse board in between.

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EXERCISES VII

1. Tabulate the maximum number of the following types of outlet which can be connected to a final subcircuit, and give the fuse link rating in each case :
   (i) 5 A socket outlets,
   (ii) Incandescent lamp holders,
   (iii) Ceiling fans,
   (iv) 15 A socket outlets,
   (v) Fixed appliances rated in excess of 15 A.

2. What capacity of socket outlets will you suggest for :
   (i) Domestic air conditioner,
   (ii) 3 KW hot water heater.
   (iii) Refrigerator,
   (iv) Electric shaver.
   (v) Portable hair dryer,
   (vi) Coffee perculator.
   Give reasons for your answers.

3. A 5 KW domestic installation is to be wired for light. Draw a wiring diagram showing supply fuses, main switch, energy meter and distribution fuse board.

4. How many incandescent lights and fans would you suggest installing on a final sub-circuit using 3/.036 cable in a place where the maximum shade temperature does not exceed 104°F. Assume supply pressure 230 V and and a maximum of four cables grouped together.

5. A consumer who was using a 100 watt refrigerator on a light circuit was advised by a polytechnic graduate to get a power circuit and install the refrigerator thereon. If the refrigerator works 16 hours a day and the cost of the complete power installation is Rs. 130, find how much he will save in 15 years if it is assumed that the installation becomes scrap after this period. The cost of light is 28 paissa per unit and power 15 paissa per unit.

CHAPTER VIII

INSTALLATION METHODS

A wiring installation must be safe, reliable and of sufficient capacity to serve the loads for which it has been designed. This chapter discusses the characteristics of different wiring systems and safety codes used in Pakistan.

THE ELECTRICITY RULES

On 27th March, 1937, the British Government, under section 37 of the Electricity Act No. IX of the year 1910, approved a set of rules and procedure to regulate the generation, transmission, supply and use of electrical energy. These rules were called "The Indian Electricity Rules 1937" and were applicable to the whole of British India. After the division of British India in 1947 and creation of Pakistan, these rules with some changes were adopted by the Government of Pakistan, and were called "The Electricity Rules 1937"

The Electricity Rules state the minimum requirements for safety and all installations must be designed and installed in strict conformity with these rules. Since these rules accommodate the regulations of Electrical Engineers and British codes of practice for electrical Installations, they are also accounted. The text of these Rules is beyond the scope of this book. Copies of it may be procured from Government Bookstalls.

Electrical installation shall be carried out only by licensed workmen authorised to undertake such work under the provision of "The Electricity Rules 1937", and under the direct supervision of a whole time supervisor having a certificate of competency of Electrical Inspector to Government for the type of work under executions. The name of the electrical supervisor and particulars of his licence are to be given on a test form to the supply company before the installation is connected to the supply.

TREE AND LOOP—IN SYSTEMS

There are two systems of connecting different points. They are the tree system and the loop-in system.

In the tree system wires are passed through the area to be served and points are teed off as required. This system becomes relatively easy when the wiring is done in roof-spaces, as the wireman has a choice in the position of runs. It is not difficult in such circumstances to select an ideal conduit route

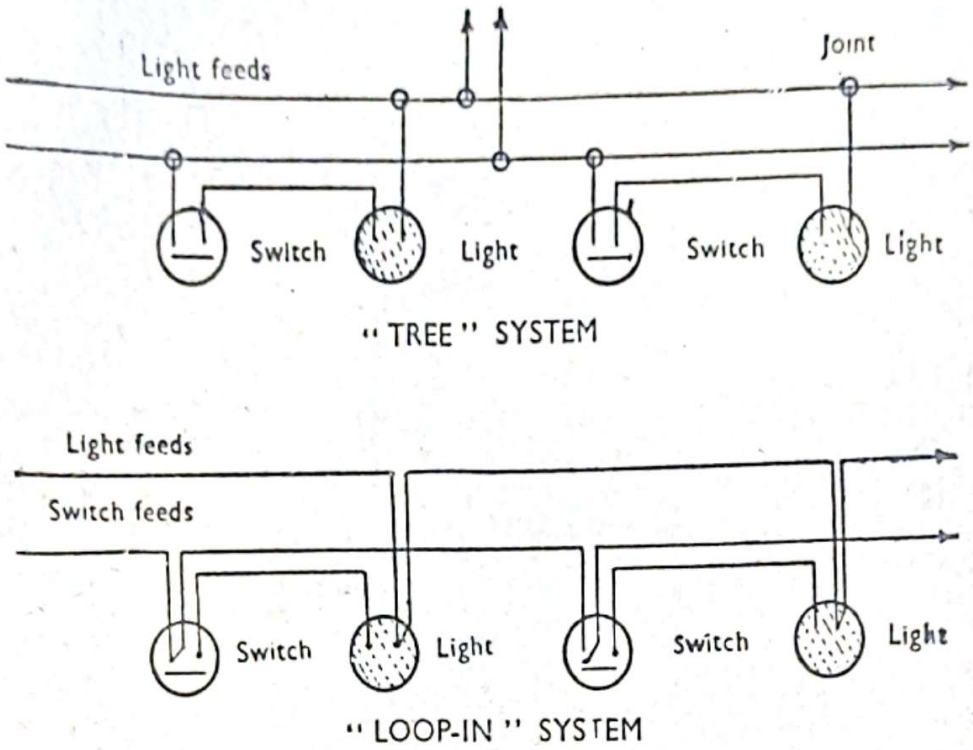


Fig. 1. Tree and loop-in system.

If a fault arises, the joints in a tree system have to be located and the cable cut open for the testing purpose. Since many joints might have to be opened in the course of testing, much unnecessary damage to the installation would often result, not only to the conductors but to flooring opened up to gain access. This is obviated to a large extent in the loop-in method.

In loop-in method the feed conductor is looped-in by bringing it direct to the terminal and then carrying it forward again to the next point to be fed. The switch and light feeds are carried round the circuit in a series of loops from one point to another until the last point on the circuit is reached.

The advantages of loop-in system apart from the absence of joints is in fault localization. No joints are concealed beneath floor or in roof spaces connections are therefore accessible for inspection and opening out merely by removing the fittings concerned. As the whole wiring system consists of a series of loops, it may be subdivided, and the loops tested separately to discover which is at fault. Thus there is no necessity to disturb conductors which are in good order, as their soundness is readily proved by the use of testing instrument of the appropriate type. Any part of the installation which does not require further investigation may be quickly restored to normal by replacing the fittings and thus closing the loop.

INSTALLATION METHODS

A wiring installation consists of a conductor along with its installation, mechanical protection and the various accessories such as switches lamp holders, etc. The best method of installation is that which provides mechanical protection to the highest degree, but of which cost is not too high. In addition to these a number of other considerations which must be taken into account are : (1) neatness in the finished job, (2) durability and long life of the installation, (3) time required to finish the job, (4) the damage to the building caused by cutting for concealed wiring, (5) voltage to be employed and (6) special conditions to withstand such as smoke, dampness, chemicals and explosive and inflammable vapours.

The various installation methods commonly used are :

(i) Cleated wiring.
(ii) Wood casing.
(iii) Conduit systems.
(iv) Lead covered wiring.
(v) Non-metallic sheathed wiring.

1. CLEATED WIRING

In cleated wiring the cables are secured to walls and ceiling by gripping in porcelain cleats. Since the cables are nearly open, there is no mechanical protection to them. This system therefore should be used where there is not any risk of damp, corrosive fumes or mechanical damage to cables. Further it should not be used where the pressure exceeds 230 volts between conductor and earth and 400 volts between the conductors.

The general appearance of cleated wiring is not very neat, but it is very cheap and easy to install. It is therefore mostly used in factories and workshops for temporary installations where neatness is not of much importance but initial cost is a major consideration.

This wiring system is very advantageous from the point of view of inspection and current loading to cables. The cable being visible can be easily inspected and is less likely to be damaged by oversight. Further the cables are better ventilated than in casing and capping or a conduit wiring system, so it is permissible to allow them a slightly higher current density.

While laying cables in cleats it is important that only one cable should be placed in one groove, where it is necessary to install many cables two or three way cleats, depending upon the number of cables, should be used. Care should be taken that cleats do not compress the insulation of the cable or are too loose to fit. The cables should be run so that they do not touch each other or the surface of the building. The runs of cables should be horizontal or vertical and never at an angle. Where the runs pass around corners they should be kept at the same distance from the wall. The cables should be installed in smooth curve with a radius of more than four times the diameter of the cable. This leaves cables free from mechanical strains.

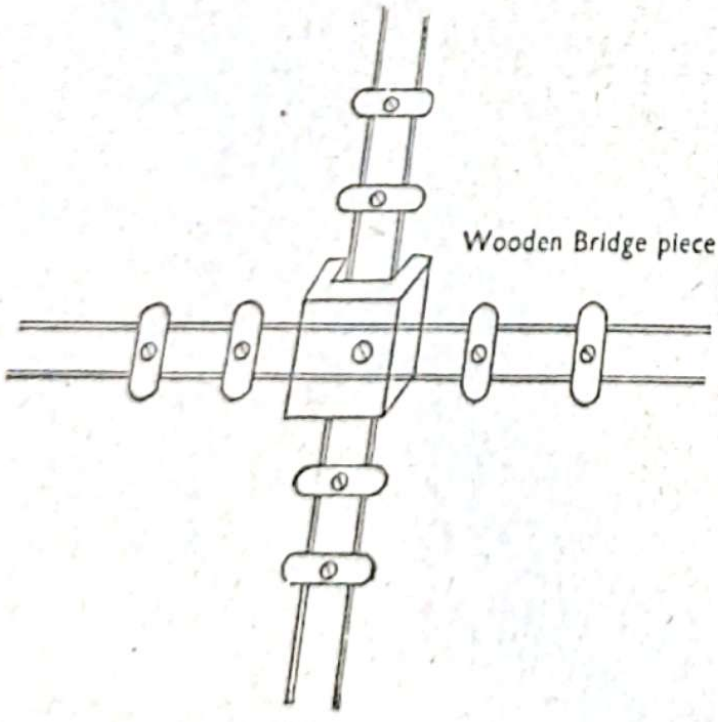


Fig. 2. Crossing of the cleated wiring.

Where the cleated cables cross each other, they must be fixed to an insulating bridge piece apable of maintaining a separation of at least one half inch between the cables of the circuits.

The spacing between the cables should not be less than twice the overall diameter of the able upto 0.3 square inches cable size. A good ventilation is obtained if the spacing between cables s kept 1 inch apart between the centre for final subcircuits, 1½ inches for submains and 2½ inches or main wiring.

Runs of cables on cleats should be kept at least 8 ft. above floor level. Special precautions hould be taken when it is necessary to run at less than 8 ft., such as for switch drops. The ables under such situations should be enclosed in conduit tubing which should be earthed. Tubing hould also be used where runs pass through walls and partitions. The holes through which the onduit passes should be as short as possible and must be filled in with fire clay or similar fire proof naterial. No space should be left around the conduit through which fire may spread. When it is necessary to run under a floor the cable must also be enclosed in conduit which must extend to at least 8 ft. above floor level or one inch below ceiling level. All conductors shall be adequately bunched to prevent abrasion,

II. WOOD-CASING :

The cables in this system, are laid in the grooves of wood-casing. The casing is then completely enclosed by a wooden cover or capping with counter-sunk brass screws on its front at intervals of about one foot. The casing and capping thus make a complete covering for the cable.

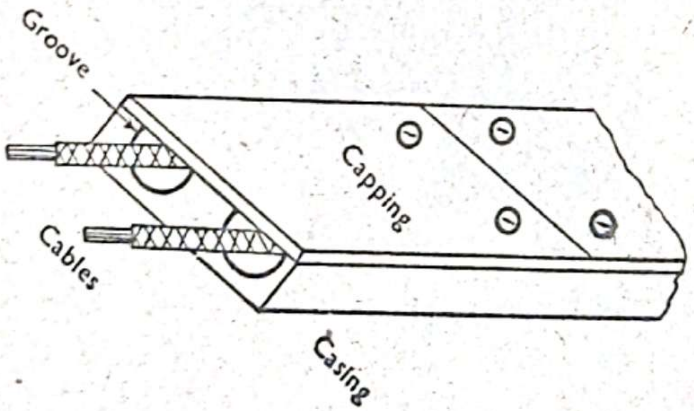


Fig. 3. Installation of cables in wood-casing.

The wood casing system is very satisfactory in dry situations. It is cheap and with reasonably skilled labour can be made to look very neat and sightly. The system offers very small mechanical protection to cables, and it should not be used for concealed work, or for runs on outside walls exposed to weather. The most serious limitations to the use of wood-casing are its inflammable nature and its capacity to absorb moisture. These two characteristics make it very undesirable in damp or ill-ventilated situations where condensation of moisture may cause leakage and finally fire in the installation.

In installing wood casing on walls and the ceiling it should be spaced from them by means of moisture proof circular porcelain cleats not less than one eighth of an inch thick. Care should be taken that corners of casing are rounded off as much as possible, and that tees off a main run are properly arranged so that cables are kept isolated.

Wires of opposite polarity shall not be installed in the same groove. Thus the neutral a phase conductors in an A.C. system shall be run in different grooves. This protects the installation fro fire if there is a short circuit between them.

When conductors pass through floors, they shall be carried in heavy gauge conduit. The condu shall be carried out to at least 12 inches above floor level and one inch below the ceiling level. Th shall be neatly led into the casing which, if required, should be protected at the floor level.

The inability to resist moisture by wood casing and capping is improved by coating them all aroun them with shellac varnish. Two coats of varnish consisting 3 lbs. of pure shellac per gallon of methylate spirits are found very suitable.

III. CONDUIT SYSTEMS

Steel conduit is a very effective way of providing an easy and accessible means for installing and removing cables in buildings without disturbing the floors or walls of the structure. It affords protection

Terminal

Tee

Ironclad Swjtch

Straight Through

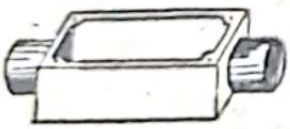
Back Entry

Angle

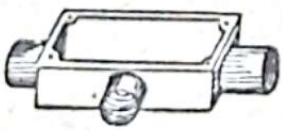
Semi Flush Switch

Ceiling Rose

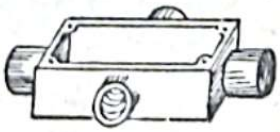
CIRCULAR JUNCTION BOXES



Straight Through



Tee



Intersection

HEAVY RECTANGULAR JUNCTION BOXES

Two Way Saddle

One Way Saddle

SADDLES

cables from injury and entirely eliminates the danger of the fire from over-heated wires. Steel conduit can be installed on the surface of walls and ceilings, as it can be concealed in concrete or plaster. A concealed conduit system prevents damage to walls and obviates unsightly runs resulting from the surface installations. Steel conduits are made in two different types, viz, light gauge for lug grip or "slip" junctions and heavy gauge for screwed junctions. The two types are made in several grades :

(1) *Close joint conduit* :

This is made from steel strip rolled and drawn to circular form. The edges in the tube are brought together but not joined mechanically.

(2) *Welded conduit* :

This is similar to light gauge conduit with the longitudinal seam brazed or welded. This type of conduit is made in light gauge as well as in heavy gauge.

(3) *Solid drawn conduit* :

This conduit is drawn from solid steel billet and is seamless. This provides a good water-tight wiring.

Steel conduits are made in eight sizes from $\frac{1}{2}''$ to $2\frac{1}{2}''$ size with a full range of fittings and accessories to faciliate its erection.

The light gauge conduits are used upto 250 volts between conductor and earth.

The close joint light gauge conduit is cheap and is suitable for ordinary surface work in dry situations.

The light gauge welded conduit is quicker to install than heavy gauge conduit. It is generally used in small houses, but can also be used in commercial installations if run above 8 ft. high. It is normally run on the surface but it can be burried in plaster in dry situations, It should not be used in damp or humid situations or buried in solid concrete floors or exposed to weather as the seams are not jointed properly and moisture may get in.

Heavy gauge conduit is expensive but it provides better mechanical protection to cables than light gauge conduit. It is liable to corrosion in acid fumes or in humid conditions.

In order to prevent corrosion conduit may be either enamelled or galvanised. Enamelling is done by dipping the steel conduit in enamel, draining and storing for about three hours. The enamel should be continuous, tough and firmly adhesive, and should not crack when the tubes are bent or set. Galvanising consists in coating the steel with zinc which does not rust or oxidise in air. The tubes are immersed in molten zinc and have to be raised to a high temperature to get the desired coating. The resulting surface should be smooth and uniform throughout. Where there is excessive moisture, acid fumes, or corrosive vapours conduit should be run concealed.

Flexible conduit is used at the termination of a run of steel conduit where cables are to be fed to an apparatus which vibrates. The noise from the apparatus is thus not transferred to the conduit and flexibility is achieved together with mechanical protection of the cables. Flexible metallic conduit is unsuitable for installations where there is excessive moisture, acid, sea salt, petrol, corrosive vapour and similar chemicals. It should be run in short length. Flexible

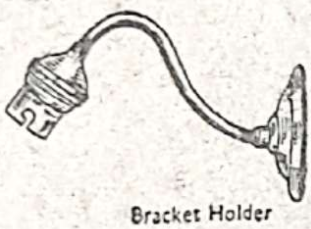
B.C. Cap Lamp

G.E.S.Cap Lamp

Ediso Screw Cap Lamp

Batten Holder

pendant Holder



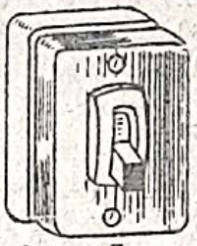
Bracket Holder

Key Holder

Rewireable

Fuse

Tumbler Switch



Oblong Type Tumbler Switch

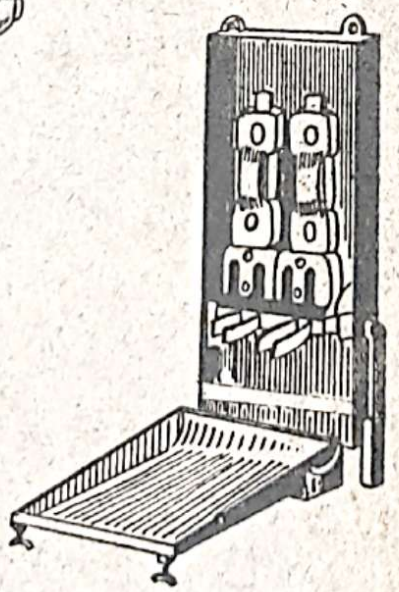
Hardwood push

Flat Back Brass Door push

Pendant push

Under Slung Type Tumbler Switch

Flush Switch



Main Switch

conduits can not be relied on to give good continuty, therefore a separate continuity conductor should be installed inside or outside the conduit.

CONDUIT FITTINGS :

(i) *Couplers* :

Couplers provides a means of connecting to conduits. When run straight lug grip couplers are used for light gauge conduits, while solid couplers and nipples are used heavy gauge type. Inspection couplers are useful to install when the length of straight run of conduit is excessive. They make it easy to remove and draw cables.

(ii) *Elbows and bends* :

Conduits are brought around the angles of walls by means of bends or elbows. Conduit bends and elbows are standardised for 90° bends. Cables between two draw-in boxes should not be drawn around more than two 90° bends, otherwise the insulation of the cable will be injured when it will be pulled around these excessive bends.

(iii) *Tees* :

Tees are used in conduit systems to make tee connections with straight runs. Where the runs are long or there are more than 90 degrees bends top outlets or circular inspection tees are advantageous, since they faciliate in drawing cables.

(iv) *Plugs and locknuts* :

Plugs are used to close the ends of a conduit so that moisture and insects may not enter the conduit system. Where a conduit enters any kind of box or other housing through a hole that is not threaded the junction between the two is made firm and secure by means of a bushing and hexagonal locknuts. The hexagonal locknut is screwed on to the threaded end of the conduit on the outside of the box, and the conduit is then passed through the conduit hole in the box ; the bushing is then screwed on to the conduit as far as it will go. A good joint is obtained if two locknuts, one inside the box and other outside are used in addition to the bushing.

(v) *Junction boxes* :

Junction boxes are used to faciliate drawing cables in conduit runs and to serve as bases for mounting various fittings. The boxes are available in black enamel or galvanised finish and can be used either for concealed or open work. The most commonly used junction box is the round type. It has a better appearance, plenty of room for drawing cable and enough room to stow slack cable. For conduits up to one inch diameter circular boxes $2\frac{3}{8}$ inch inside diameter should be used. Larger boxes $3\frac{5}{8}$ inch inside diameter may be used for conduit upto $1\frac{1}{4}$ inch diameter. For conduits above this size rectangular boxes should be used. They have more space than circular boxes and can accommodate larger size cables which are usually run in conduits of more than $1\frac{1}{4}$ inch size. The rectangular boxes are made in different sizes and can be selected large enough to permit easy drawing.

(vi) *Saddles* :

In surface installations, saddles are used to hold conduit to the wall, so that it lies flat against plaster. Saddles are classified according to the number of conduits they can hold. Thus a two-way saddle can hold two conduits and a six-way saddle six conduits side by side. Saddles should be

placed at intervels of about 3 feet along the conduit, and within 4 inches of each fitting or accessory. Rawal plugs or wooden gutties should be used when installing to concrete, stone, brick or plaster walls

Where it is necessary, to keep the conduit away from wall surface either spacing saddles should be used or the conduit shall be fixed on wooden strip base secured by ordinary saddles. This prevents the corrosion of the conduit and collection of dirt and dust behind the conduit.

INSTALLING CONDUIT

In constructing a steel conduit system, first make sure that the conduit used is of sufficient capacity to accomodate the cables. Appendix IV provides capacity of conduits for different cables. These figures apply only where the cables are not drawn round more than two 90° bends between draw-in boxes.

In preparing conduit cuts must be straight to allow maximum contact when butted. Conduit should be cut with a hack-saw in preference to a pipe cutter, as the latter tends to cause a burr inside the conduit. Threads should be cut with good, clean and well lubricated dies. After threading ends require reaming to remove any ragged edge, and the conduit should be swabbed through to remove any loose material liable to damage cables when drawn-in.

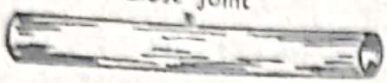
When a conduit is joined to a junction box or any other fitting, sufficient threads should be cut to allow the threaded portion of the conduit to occupy the whole receiving threads in the box or fitting. Where joints are made between conduits, the ends should but together in coupler.

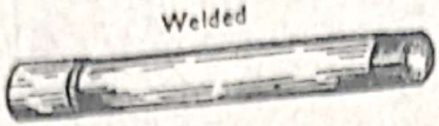
The whole system should be provided with draw-in points to faciliate cable drawing in the conduit, and they should be suitably located. When there is a long straight run of conduit it is good practice to keep draw-in points not exceeding 14 ft. apart. The system should be designed so that not more than two right-angled bends occur between the draw-in-points. These bends should be of inside radius not less than $2\frac{1}{2}$ times the diameter of conduit.

When heavy gauge conduit is fixed to the surface of bricks and concrete walls in buildings subject to wide change of temperature, condensation of moisture takes place in the conduit. Moisture may cause damage to the insulation of cable. Condensation is prevented if the runs of conduit are angled slightly to provide drainage by way of out-lets at the lowest point in the system. In addition there should be openings at higher points to allow air to circulate readily and thus to limit the amount of condensation which will occur. The openings should be designed in such a manner that entry of insects is prevented

In garages and places where petrol driven vehicles are stored or repaired all apparatus, unless flameproof or totally enclosed, must be fixed atleast 4 ft. above the general floor level. In situations where inflammable dust, vapour or gas is present the cable should be drawn in solid drawn steel conduit, and all the switches and fittings must be flame-proof type. Where a conduit run leaves the hazardous situation a flame-proof sealing box should be used.

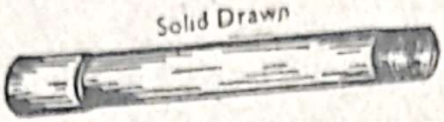
Heavy gauge screwed conduit should be used where an installations is exposed to rain or condensed moisture. All outlets, switches and fittings should be perfectly water tight.


Close Joint


Welded

Welded

Light Gauge Canduit


Solid Drawn

Heavy Gauge Conduit

Flexible Conduit

CONDUITS

olid Coupler

Lug Grip Coupler

Split Coupler

Earthing Coupler

Inspection Coupler

Nipple

COUPLERS

Solid Elbow

Lug Grip Solid Elbow

Split Elbow

Inspection Elbow

Top outlet Elbow

Circular Inspection

ELBOWS

A copper wire should be run alongside the conduit as earth continuity conductor. This makes all the metal work of the system at earth potential and provides a low resistance path to short circuit currents to earth. Running this separate wire does not mean that continuity of conduit should not be good. All joints should be clean and tight and painted with aluminium paint before jointing to prevent corrosion. This, on one hand, provides good protection for cables against fumes and moisture and on the other hand provides an additional earth path when the continuity conductor becomes disconnected for some reason.

DRAWING CABLES INTO CONDUIT

After the conduit has been installed, cables must be pulled into the conduit. On new installations as well as those in humid conditions, moisture accumulates inside the conduit. Before installing cables the bore of the conduit must be dry and free from condensed moisture. This is achieved by drawing a swab through the whole conduit system. A thin steel wire, called fish-wire, drawn during construction into the conduit is used for pulling electric cables when the installation is complete. One method of connecting the cables to be pulled through, the cables are bared for sufficient length and then bent back and twisted to form an eye. The ends of the eye are twisted around the bare cable to make a taped joint.. This is then taped from the eye and is rubbed freely with french chalk to make easy running.

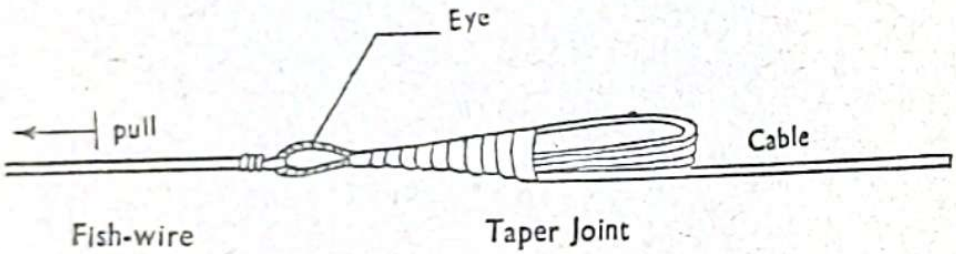


Fig. 4. Fixing cable to fish-wire for pulling through conduit.

The cables should be carefully fed into conduit to avoid kinks or cross overs. Some slack should also be left at inspection points to ease the removal of cables at a later date, if it is necessary. In preparing ends for connection, the insulation of the cable should not be cut further than is needed for entry to the terminal. Care should be taken not to nick the conductors while stripping. No strand should be cut out for easier connection. The braid or sheath must be taken back at least $\frac{1}{2}$ inch from the end of the insulation. The tails should be long enough to avoid any strain on the terminals.

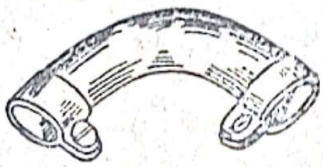
IV. LEAD-COVERED WIRING

Lead-covered cable afford good protection against moisture ; but in view of its liability to electrolytic corrosion it must be erected with special care. Electrolytic corrosion arises when minute leakage currents in the lead sheating escape at a point where moisture is present, and the action is rapid and destructive. For this reason lead sheathing must be metallically continuous throughout, and it must be efficiently earthed. Fittings can now be obtained for use with lead-covered wires, which give a water-tight and electrically continuous joint with soldering. Lead-covered cables are not suitable for burying in plaster or concrete. If run in wood casing, or secured by wood battens, the wood should first be well painted. If not the lead will ultimately be corroded by the acids in the wood.

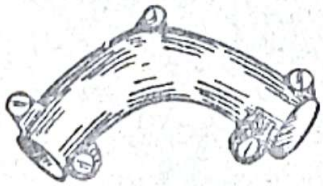
A large number of wiring systems using two and three-core cables sheathed with a tough lead alloy have been developed in recent years, and have come into very general use. In these systems the practice of looping-in has been discarded. Special connector boxes are supplied for the purpose of containing the conductor joints and for bonding the metallic sheathing. Experience has shown that

Solid Bend Internal Thread

Solid Bend External thread



Lug-Grip Bend



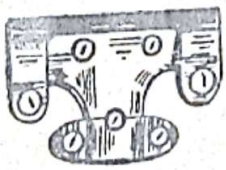
Split Bend

Inspection Bend

Top outlet Bend

BENDS

Solid Tee



Lug Grip Tee

Split Tee

Inspection Tee

Top Outlet Tee

Circular Inspection Tee

TEES

Hexagonal head Solid plug

Slotted Solid plug

Heavy Hexagonal Locknut

Light Hexogonal Locknut

Circular Locknut

PLUGS & LOCKNUTS

house wiring carried out with this system is less costly than with steel conduit. These systems ha also been found particularly advantageous in the wiring of old buildings in which some amount of surfac wiring is necessary. The unobtrusive nature of the lead alloy clad wire renders it very suitable for u in such circumstances. The success of the lead alloy clad system has undoubtedly been largely due the development of a suitably lead alloy, which is flexible enough to enable the cable to be easily ben yet stiff enough to enable straight runs to be carried out with a minimum number of cleats.

The Henley system of wiring employs a special design of cable. The cables are single, twin three core, and consist of tinned copper wires insulated with pure and vulcanised rubber, taped wit proofed tape of a distinctive colour. The whole is then vulcanised together and sheated over with solid drawn tube of lead alloy. Special clips and bonding clamps are used to make the continuity of th lead-alloy covering continuous throughout and enable every part of the installation to be at earth potential.

The joint boxes, straight throughs, tees, and universals, consist of three compartments only back plate, cover, and bonding clamps. These are simple to install owing to the use of porcelain-sheathed connectors, and the sure slipping-into.portion of the bonding clamps and tightening of bonding screws. The covers are of the "snap-on" type. Indents are provided to enable portions to be easily removed by pliers for cables larger than 3/.029 twin, for which the covers are supplied slotted. Jointing and bonding can be inspected by simply removing the cover, and alterations and additions to the connections can easily be made. The figure shows the method of connection of the cable base plate and cover, and bonding clamps used to ensure continuity of the lead-sheathing in the system.

In Pakistan lead-sheathed cables are usually used up to 250 volts and run on wood battens supported by means of brass buckle clips spaced at intervels of 4 inches both vertically and horizontally. The wiring is carried out in looping-in system and the use of joint boxes is entirely eliminated. Where the cable terminates for entry in switches, ceiling roses and sockets, a circular wooden block or rectangular wooden board, whichever suitable, is provided.

While installing the system care should be taken in fixing the buckle clips. The heads screws shall be set level with the surface of the clips so the lead sheathing will not be damaged. When the V.I.R. insulation of lead-sheathing cable has to be stripped for joints, the metal sheathing must be only nicked, not cut, and the insulation between the metal sheath and the conductor shall be of rubber only.

Smooth circular bends should be provided at the points where the cable is turned, and the bends shall not be less than three inches radius to avoid strain on the cable. At places where mechanical damage to the conductor may occur, the lead-sheathed cable must be covered with a sheet metal protective covering. The base of protective covering shall be flushed with the surface of the wall. It is good practice to install such protective covering if the cables pass to within six feet of the floor level. Where the lead-sheathed cable passes through floors, it should be taken in heavy gauge steel conduit. The conduit should extend six feet above floor and flush with the ceiling below. Cable passing through walls shall be enclosed in heavy gauge conduit. The conduit shall extend one inch beyond the wall on each side. All lead sheathing shall be well bonded through out its whole length with earth continuity conductor.

V. NON-METALLIC SHEATHED WIRING

The use of a non-metallic sheath for cables for house wiring avoids the necessity for bonding the cable.

The cables generally used for this system in Pakistan are T.R.S. or P.V.C. insulated and P.V.C. sheathed type. Overseas "Permanite" cables which are unaffected by oil, acid and alkalies and "Maconite" cables which are non-hygroscope and unaffected by extremes of temperature have also been used and found satisfactory for surface installation.

The T.R.S. and P.V.C. sheathed cables can either be run on the surface of walls or ceiling, on teak wood battens, or buried directly in plaster. When used on battens, the cables are secured to the surface by counter sunk brass wood screws into Rawal plugs or wooden gutties, which are not more than three inches apart. The cable is held by brass buckle clips to the battens. The clips are fastened to the battens by brass nails or brass screws $\frac{5}{8}$" long at intervals of about 6 inches on a vertical run and about 4 inches on a horizontal run.

All runs in this system should be vertical or horizontal and never diagonal. The wood batten should be continuous throughout and kept as straight as possible. Where bends occur they should be smooth and circular with a radius not less than 3 inches. When two runs of sheath cable cross, they should be made at 90° and wooden spacers, with at least $\frac{1}{2}$ inch spacing between the two sets, should be provided.

Cables when taken through floors, shall be enclosed in heavy gauge steel conduit, extending six inches above the floor and flush with the ceiling below. The ends of all conduits shall be neatly bushed with porcelain or wood. When passed through walls, the cables should be taken through heavy gauge steel conduit extending one inch beyond the wall on each side.

Non-metallic sheathed wiring shall not be used for voltages greater than 250 volts between conductor and earth. For medium voltage, the cable should be run in heavy gauge steel conduit.

It must be remembered that the use of wire with a non-metallic sheath does not avoid the necessity of earthing the metallic frame work of electrical apparatus. The fact that a non-metallic cable sheath gives no convenient earthing connection for such apparatus must be regarded as a possible disadvantage in many circumstances.

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EXERCISES VIII

1. Describe the most likely sources of failure in conductors installed under the following conditions, and discuss the precautions you would observe to reduce risk of failure to the minimum.
   (i) V.I.R. cable drawn into heavy-gauge conduits, fixed to the surface of brick and concrete walls in a building subject to wide temperature changes.
   (ii) T.R.S. cables run externally between buildings.

2. What installation method you would adopt under the following conditions :
   (a) in situations where inflammable dust, vapour, or gas may be present ?
   (b) where exposed to rain or condensed moisture ?

3. Describe fully the precautions to be taken in constructing a metallic conduit installation.

4. The following faults are of frequent occurence in screwed conduit installations :
   (i) high resistance across conduit joints.
   (ii) rusting at entries to conduit fittings.
   (iii) condensation of water.
   (iv) blockages in conduit after erection.

   Explain in each case, the methods you would adopt to avoid these faults when installing conduit wiring.

5. What are the essentials of good workmanship in the following cases :
   (i) care of V.I.R. cables when drawn into conduit, and preparation of ends ready for connection into pinching terminals ?
   (ii) preparation of screwed conduits before, and treatment after installation ?
   (iii) termination of P.V.C. sheathed cable at a ceiling outlet for a lighting point ?

6. What type of installations you would recommend in the following situations ?
   (i) a chemical work.
   (ii) a farm.
   (iii) a boiler house.
   (iv) a wood working shop.
   (v) an auto-shop.

   Give reasons for your selection in each case and detail any special precautions necessary during installation. (Deal with cables, cable enclosures and fittings only, ignoring accessories, control gear and fittings.)

7. What are the advantages of loop-in system of connection over tree system ? Which system of connection is used in Pakistan ?

8. Using Appendix IV find the size of heavy gauge conduits for the following number and size of cables.
   (i) 4 - 3/.029 inch (ii) 6 - 7/.029 inch
   (iii) 2 - 7/.064 inch (iv) 2 - 19/.083 inch

9. Describe Henlay's system of lead-covered wiring and compare it with the system used in Pakistan.

10. What precautions will be taken in installing
    (i) wood casing ?
    (ii) cleated wiring ?
    (iii) non-metallic sheathed wiring ?

11. Explain the procedure and precautions to be adopted in :
    (i) installing conduit.
    (ii) drawing cables in conduit.
    (iii) passing cleated wiring through floors.

CHAPTER IX

PROTECTIVE EARTHING

Protective earthing is the term used to denote an earth circuit which connects the dead metal parts of an electrical installation to the general mass of earth. This circuit protects against

(1) the danger of shock to anybody who touches the exposed and apparently harmless dead metallic parts of equipment.

(2) the danger of leakages through accidental and partial earth contacts which sets up arcing or local heating and thus give rise to a risk of fire.

The neutral point of supply is normally earthed in a power station or substation, when a break down of insulation in such a system occurs between line and earthed metal of an apparatus or equipment, a fault current flows to earth. The amount of fault current is limited by the resistance to earth of the circuit, and is large when the resistance is small. These large currents provide earth-leakage protection by blowing fuses or operating an earth fault relay. The apparatus is thus dis-connected from the supply automatically, and any body touching it is protected from the electric shock. This can be better explained by an example. Consider that a 230 volt refrigerator is protected by a 10 A fuse and the earth connection is poor. The result will be a resistance of 40 ohms between the refrigerator and earth occurs due to the failure of the motor insulation. The fault current that will flow is :

$$\frac{\text{Volts}}{\text{resistance}} = \frac{230}{40} = 5.75 \text{ Amp.}$$

Since the protective fuse is 10 A capacity, and the fault current is 5.75 amp, the fuse will fail below.

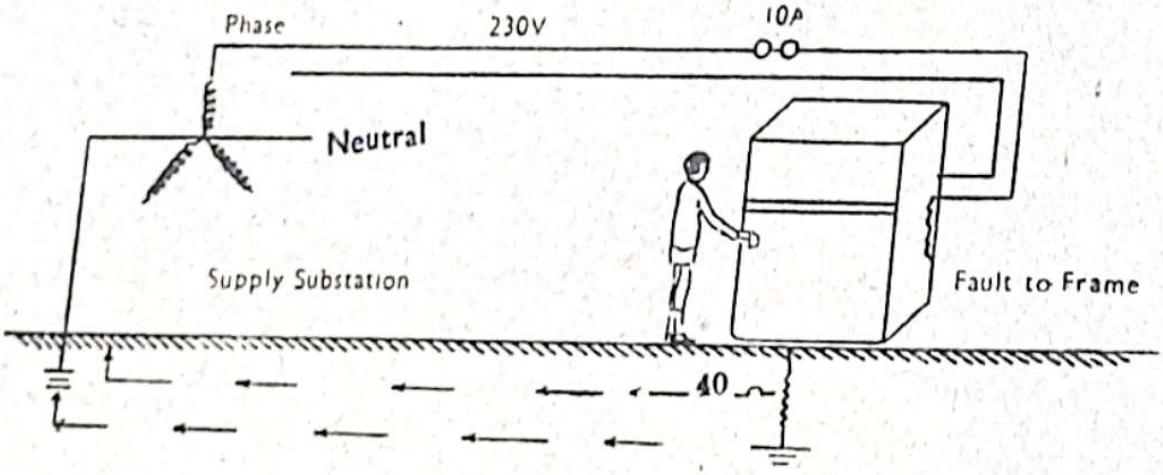


Fig. 1. Diagram showing how a leakage gives shock to a person touching the metal.

Danger now exists on the refrigerator because the potential difference between it and earth is 230 volts. Any person standing on the ground and touching the refrigerator will have the shock of this voltage, which is sufficient to kill him. Moreover, heat produced will be

$$I^2R = (5.75)^2 = 1320 \text{ watts.}$$

This may increase the temperature of the refrigerator materials to the ignition point, and it may catch fire.

If a good earthing connection of the order of one ohm instead of 40 ohms is kept, the current, when refrigerator becomes faulty, shall be 233 amp instead of 5.75 amp. This is sufficient to blow a 10 A fuse and to isolate the refrigerator from the supply.

I.E.E. REGULATIONS FOR EARTHING :

The Institute of Electrical Engineers has set out vigorous requirements for efficient earthing in their wiring regulations. According to the regulations all non-current-carrying metal used for covering electrical conductors or forming part of electrical equipment must be earthed. The exceptions to this requirement are lamp holders, lamp caps, short isolated lengths of conduit used as additional protection for sheathed cables and short unexposed lengths of pipe protecting cleated wiring passing through wall or floor.

Where an installation is fed with other services, such as gas or water, along with electricity, the pipe work of the other services should be bonded to and earthed by the earth continuity conductor of the installation. Structural steel work should not be used as part of an earth continuity conductor unless the joints are metal to metal. Where possible it should be bonded to earth continuity conductor of the installation.

In bath-rooms, where the incorrect use of portable apparatus is liable to cause fatal shocks, the use of any exposed metal covering electrical conductors must be avoided unless earthing of the highest efficiency can be carried out. Thus lamp holders and switches must be completely shrouded with insulation.

The electrical resistance of the earth continuity conductor formed by metallic sheathing or separate wire, when measured from the point or connection to the earth electrode to any other portion in the completed installation, shall not exceed one ohm. This resistance includes that of the conductor actually connecting the metallic sheathing to the earth electrode.

Earth leakage protection shall be provided for all installations subject to the following exceptions :

(1) where the earth-leakage current can be provided to have a value greater than the setting of the controlling fuse or circuit breaker.

(2) where the setting of the fuse or circuit breaker does not exceed 100 ampere and the metal work of the installation is earthed to an urban system of metallic water mains having metal to metal joints.

The metal conductor connecting the sheathing to the earth electrode must be at least 0.0045 sq. inches in cross-section or 14 S.W.G., and not less than half the cross-sectional area of the largest supply conductor, with a maximum of 0.1 sq. inches or 3/0 S.W.G. This conductor if in an exposed situation is preferably phosphor-bronze, must be provided with soldering sockets, and be attached to conduit, cable sheath or earth electrode by a substantial clamp of non-rusting metal.

COMPONENTS OF EARTHING SYSTEM :

An earthing system mainly comprises of three parts.

(i) earth continuity conductor.
(ii) earth lead.
(iii) earth electrode.

The exposed metal work is connected to earth through the combination of earth continuity conductor, earthing lead and earth electrode. The combined resistance according to I.E.E. regulation shall not be more than one ohm.

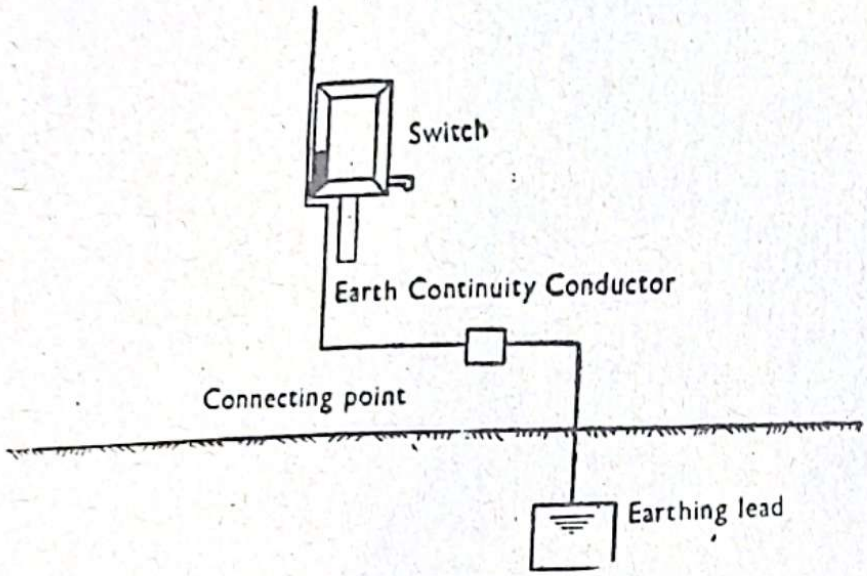
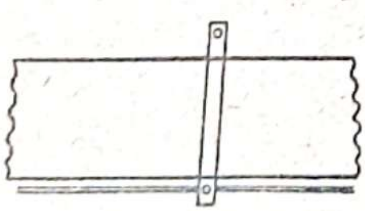


Fig. 2. Components of earthing system.

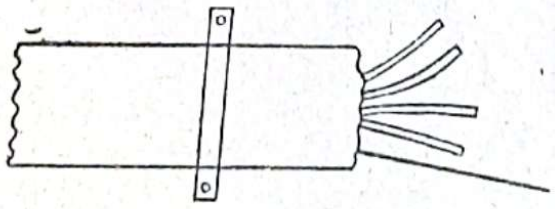
EARTH CONTINUITY CONDUCTOR :

The earth continuity conductor joins or bonds together all the non-current carrying metal parts of an electrical installation, apparatus or machine such as conduit, metal casing of switches, switch fuses, fuse distribution boards, motors, and all the metal frame work on which electrical apparatus and machines are mounted. The size of this earth continuity conductor as already mentioned in I.E.E. regulations depends on the largest size cable in the circuit that is protected, and is to be not less than half that size in cross-sectional area. Appendix V at the back of this book gives the recommended sizes of copper wires and strips for each cable used.

When an earth continuity conductor is installed with a conduit, it can be taken inside or outside of it. To protect the conductor against the risk of mechanical damage, it is necessary to install it inside the conduit if the conduit is taken below the height of 5 ft. in buildings.



Earth continuity conductor run outside the conduit.



Earth continuity conductor run inside the conduit.

Fig. 3. Installation of earth continu ity conductor in conduit.

The continuity conductor should be firmly held by conduit clips when installed outside the conduit should be stretched along the conduit, and should not be kept loose. This gives a work-man-like appearance to the installation and inspires the consumer with much confidence in the wiring work.

In bonding the earth continuity conductor to the casing of apparatus, it should be tightly clamped by a special screw provided on the apparatus. It should not be connected to a bolt or screw securing the apparatus to its fixture.

On battens the earth continuity conductor should be installed underneath the sheathed cable, and should be held firmly by buckle clamps. Special cables incorporating a correct size bare copper wire are also manufactured by Pakistan Cables Ltd. When using such cables separate continuity conductor need not be installed.

EARTHING LEADS

The earthing lead conductor joins the earth electrode and earth continuity conductor. Depending upon the load, two types of earthing leads are used. These are hard drawn copper wire and copper strip. In smaller installations upto 200 amperes, copper wire is mostly used and earth continuity conductors are all brought to one or more connecting points, depending upon the size of installation. The earthing leads are then run from these points to the electrode.

In order to increase the safety of an installation, copper wire earthing leads should be run in duplicate for each earth plate or electrode, and each lead must be capable of carrying the full fault current. The area of each earthing lead must not be less than half the area of current carrying conductor in the circuit and must not be smaller than 8 S.W.G. The earthing leads should be drawn in galvanised iron pipe to the electrode to protect them against mechanical damage and corrosion. The pipe can also be used, if necessary, to guide water to the plate in order to keep the surroundings of the plate artificially damp. Appendix V can be used to determine the size of earth lead conductor.

When conductors larger than 37/.083 are used or over 200 amps are taken by an installation, copper strips should be used as the earth lead. In this case earth leads are not duplicated as in case of bare copper wires. It is customery to run the strip throughout the inatallation and all continuity conductors from exposed metal-works are connected to this strip. The lead finally terminates at the electrodes. In order to isolate the plate at the time of testing of the earth installation, a removable link should be provided at the strip. The link should be made at a convenient place and should only be accessible to authorized persons. The best way is to install the link under a man hole cover in a concrete recess or some similar arrangement. To protect the earthing strip against mechanical injury it should be installed at least one foot below the ground level.

EARTH ELECTRODES :

The earth electrode is that part of the earthing system which is connected to the earthing lead at one end the general mass of earth on the other. The potential at the earth electrode is that of the earth, and the contact resistance between the electrode and earth should be extremely low. A zero resistance is the best.

It has been mentioned that a connection to a main water service for a domestic load up to 12 Kw is usually considered a satisfactory requirement for earth electrodes. This, of course, is based upon the prevailing practice, whereby water supply is obtained by cast iron mains and

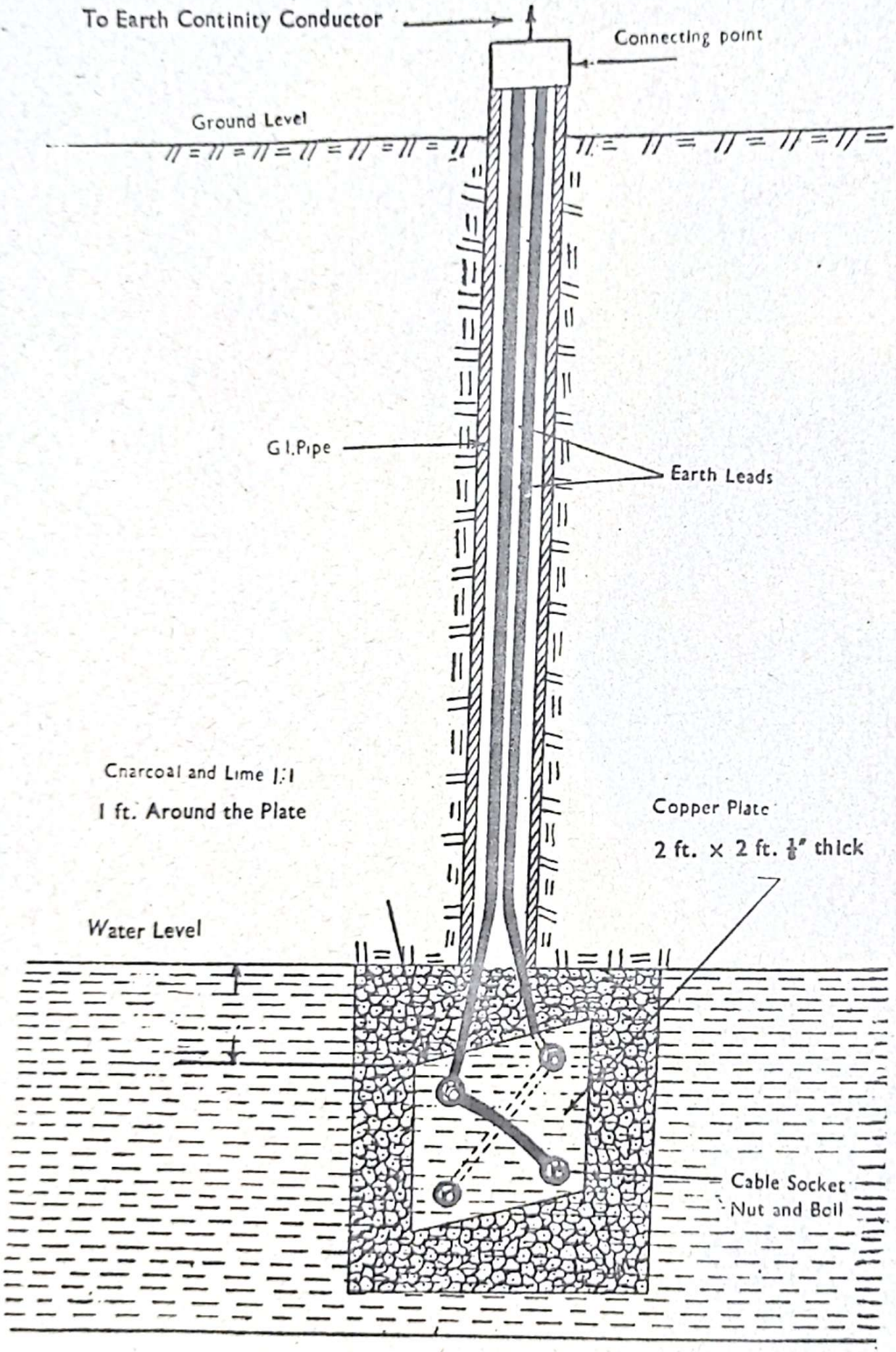


Fig. 3. Installation of an Earth Plate

galvanised iron service pipes are in metallic connection at joints. Modifications of the methods of water supply, which have been adopted now include,

(1) the electrical isolation of service pipes from mains.

(2) use non metallic asbestos cement pipes for mains.

It is evident where these practices prevail, a water service will not give a satisfactory earth connection. Moreover, at some places although cast iron and galvanised iron pipes are used, their joints are made water tight by insulating materials such as hemp. Sections of pipe are thus cut off electrically, and the line will not provide a good earth connection. For these reasons it is recommended that electrical continuity and a good earth connection in water service pipes be investigated before earthing a domestic installation. Otherwise any connection of exposed metal work of electrical wiring or appliances to such a water service would be dangerous.

In rural districts like Larkana without public water supply, and where water pipe does not provide good earth connection, the satisfactory domestic earthing of exposed metal work entails the provision of an earthing electrode. In larger installations above 12 Kw where large fault currents could flow, earthing of the installation is done by earthing electrodes even if satisfactory mains are available. This is to confine the dangerous voltages that arise due to fault currents to installation premises rather to spread over a wide area.

In Pakistan a plate of copper or galvanised iron is used as an earthing electrode. Mostly the earth plate is 2 ft. × 2 ft. in area and $\frac{1}{4}$ inch thick for galvanised iron and $\frac{1}{8}$ inch thick for copper. The plate is installed at least one feet below water level in an upright position in the ground. This is completely surrounded by a bed of about 1 ft. of charcoal mixed with lime packed hard. The mixture increases the continuity to earth. Coal can be used instead of charcoal, but it is not as good a moisture retaining substance as charcoal. Coke should not be used as it has corrosive effect, especially on copper.

The contact resistance between an electrode and the earth surrounding varies (1) with the soil and (2) with the amount of moisture around it during the year. If lower resistance (a fraction of an ohm) is not acquired with one earth plate, more plates should be connected in parallel, keeping each one at least 10 ft. away from the other, until the required value of resistance has been obtained.

For domestic installations only one earth connection (or earth plate) is sufficient, but it is much safer to install two since one will ensure earthing if the other fails. In factories or places where load is above 12 Kw or electrical apparatus or machines like transformers, motors, etc. are present at least two plates should be installed at a distance of at least 20 ft. from the other, and one of the plates should be as near as possible to the apparatus which will produce the largest fault current.

It is important that each copper earthing lead should be secured to the plate in at least two places diagonally to obtain good contact. The wire or strip can be clamped by brass, copper or galvanised iron bolts and washers making sure that both surfaces are perfectly clean before joining. The bolts shall be well tightened and coated with bitumen before burying the plate in the ground. This prevents corrosion at the joints.

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EXERCISES IX

1. (a) What requirements do the I.E.E. regulations specify for the cross-sectional area of earthing leads ?
   (b) Find the cross-sectional area of the earthing lead for 7/.064 mains without using tables.

2. Where metal conduits are used as enclosures for cables, regulations require
   (a) they shall be earthed, and
   (b) there shall be electrical and mechanical continuity across all joints.
      (i) Describe the requirements for compliance with (a) and sketch a suitable form of earth clamp.
      (ii) Discuss the methods you would use to ensure compliance with (b) for both heavy gauge screwed and light gauge conduits.

3. What are the conditions in which metal lighting fittings need not be earthed ?

4. In your own words interpret regulations covering requirements for earthing in reference to :
   (i) metal work (such as conduit and cable sheaths).
   (ii) structural steel work.
   (iii) pipe work of other services.

5. Define the following terms :
   (a) earth continuity conductor.
   (b) earthing lead.
   (c) earth plate.
   (d) live conductor.
   (e) insulation.

6. Explain with neat sketches how to install an earth for a domestic installation where the water pipe cannot be utilized for earthing.

7. Using Appendix V find the size of earth continuity conductor for (a) 3/.029 (b) 7/.054 (c) 19.044 (d) 37/.083 and (e) 61/.103 mains. Verify your answers with calculations.

CHAPTER X

TESTING OF AN INSTALLATION

The Electricity Rules 1937, Art· 25 prescribes that electricity supply undertakings shall not connect an installation unless they are satisfied that the connection would not cause a leakage exceeding one five-thousandth part of the maximum supply demanded by the installation. The rule pre-supposes that some form of test be carried out without specifically mentioning the precise nature of requirements.

I. E. E. REGULATIONS FOR TESTING INSTALLATIONS

According to I. E. E. Regulations, for the electrical equipment of buildings it is necessary to carry out the following tests to make sure that the installation is safe.

(1) POLARITY OF SWITCHES (Regulation 504)

This ensures that all single pole switches are on the live side of the apparatus they control.

(2) INSULATION TESTS (Regulation 501-503)

(a) Between each conductor and earth
(b) Between conductors themselves.

These prescribe that electrical installations shall be tested on completion with a direct current pressure of not less than twice the working pressure, and that the insulation resistance of a completed installation shall not be less than 50 megohms divided by the number of outlets (points and switch positions) in the circuit, although no installation need have an insulation resistance greater than 1 meg-ohm.

$$\text{i.e minimum insulation resistance} = \frac{\text{50 Megohm}}{\text{No. of outlets}}.$$

For an incomplete installation, i.e. one without fittings, lamps etc., the minimum insulation resistance should be not less than 100 megohms divided by the number of outlets.

Where P. V. C. insulated cables are used, the equivalent values are 12½ and 25 megohms divided by the number of outlets. The tests should be made (1) between each conductor and earth, and (b) between the conductors themselves.

(3) EARTH CONTINUITY CONDUCTOR TEST (Regulation 508C)

This briefly states that, provided no inductor (choke) is incorporated, it is normally satisfactory, where steel conduit forms the earth-continuity conductor, if a value of resistance not exceeding ½ ohm is obtained.

INSTRUMENT FOR TESTING

(1) *Test Lamp*

One of the most commonly used instrument by electricians is a test lamp. It consists of a 15 W 230 volt incandescent lamp fitted in a lamp holder, two insulated leads about 2 ft in length are taken out from the lamp holder by an insulated cable, and the insulation at the ends of cable is removed. This can be used for checking the supply pressure, diagonosing faults and testing polarity. Care should be taken when using this instrument since it may give rise to dangerous accidents due to the bursting of the lamp in the electricians face.

(2) *Magger Insulation Tester*

The Magger insulation tester is an instrument by means of which the measured value of a resistance is directly indicated on a scale independent of voltage. The instrument consists of two primary elements, a hand driven permanent magnet type D. C. generator, and the instrument which indicates the value of resistance. The instrument is marked from zero to infinity and gives readings directly in ohms when the resistance whose value is to be determined is connected across line and earth terminals and the handle is turned.

For testing an installation a Magger twice the declared voltage shall be used. Thus for a domestic installation up to 250 volts, a 500 volts Magger is required.

(3) *Continuity tester*

A continuity tester, as its name shows. is an instrument for performing continuity tests. The instrument can be made easily by an electrician. It consists of a box in which a 3 volt battery of dry cells is fitted in series with a 3 volt lamp

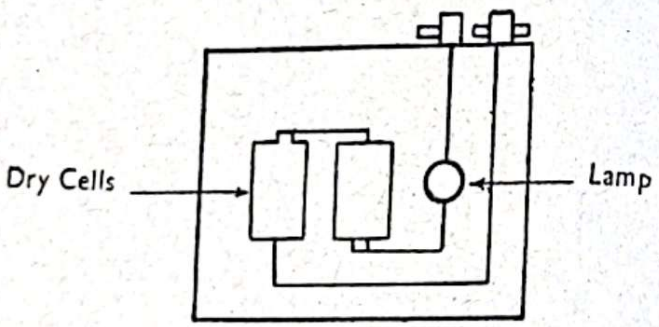


Fig. 1. Continuity tester

as shown in the figure above. When testing the continuity between two wires, their ends are connected by the terminals of the continuity tester. The lamp glows if there is continuity between them.

TESTING PROCEDURES

(1) *Polarity of switches*

The polarity of single phase switches can be determined by using either
(a) a test lamp, (b) a continuty tester or (c) a Magger tester.

When electrical supply is available the polarity can be tested by a test lamp. When the test lamp is connected between the phase and earth it should glow as full installation voltage is now applied across it. When it is connected between neutral and earth the lamp should not glow. A line conductor can be checked all through a circuit, and it can be ascertained whether all switches are on the line wire by applying the test to each of them.

When supply is not available the test lamp method of testing polarity cannot be applied. A continuity tester can be used under these circumstances. The method consists of testing continuity of the neutral wire through the installation. Starting from the main switch fuse (main switch and all single pole switches off), the continuity should be checked from the neutral link of the main switch, and through to the light points and socket outlets. If there is no continuity in the neutral wire, then some switch is wrongly connected to the neutral wire instead of the phase wire. The error can be eliminated easily.

The polarity of switches can also be ascertained by replacing the continuity tester with a Magger and adopting the test procedure as mentioned above. If the Magger pointer registers a value up to a half ohm the polarity is correct, otherwise some single pole switch is wrongly connected to the neutral, and should be placed correctly.

(2) Insulation :

As mentioned before two types of insulation tests should be rendered before connecting, the insulation to the supply. These tests consist of (a) a test between the insulated conductors and earth and (b) a test between insulated conductors themselves including the neutral.

(a) *Insulation test to earth* :

In order to make the test, disconnect the supply by opening the main switch and withdrawing its main fuses. Keep intact all the fuses of the main distribution fuse board, and insert all lamps closing all single pole switches. If the installation is incomplete, the conductors at each point and switch positions must be joined together. Join together the contacts of main fuses by a wire on the insulation side, and connect them to one terminal of the Magger insulation tester. The other terminal of the Magger insulation tester should be connected to the main earth. The second connection should also be made to the conduit in which the wiring is run or lead sheathing if lead covered cable is used. In these cases it is necessary that their continuity to earth has been previously established.

In circuits having two way stair-case wiring, two test readings should be taken. One switch in each pair of stair-case wiring should be changed over before taking the second test. It should be ensured that both interswitch wires are included in the test. If the result of the test is in accordance with the regulations previously mentioned, the installation may be considered sound as far as resistance to earth is considered.

If, however, the values obtained are not satisfactory, withdraw all fuses, from the main distribution board and test again. This test will only include the portion of the installation from the main switch to the bus-bars of the main distribution fuse board. If the fault does not lie in this portion of installation then test each final sub-circuit in turn by inserting its fuses in the main distribution fuse board until the faulty circuit or circuits are discovered.

) *Insulation between conductors* :

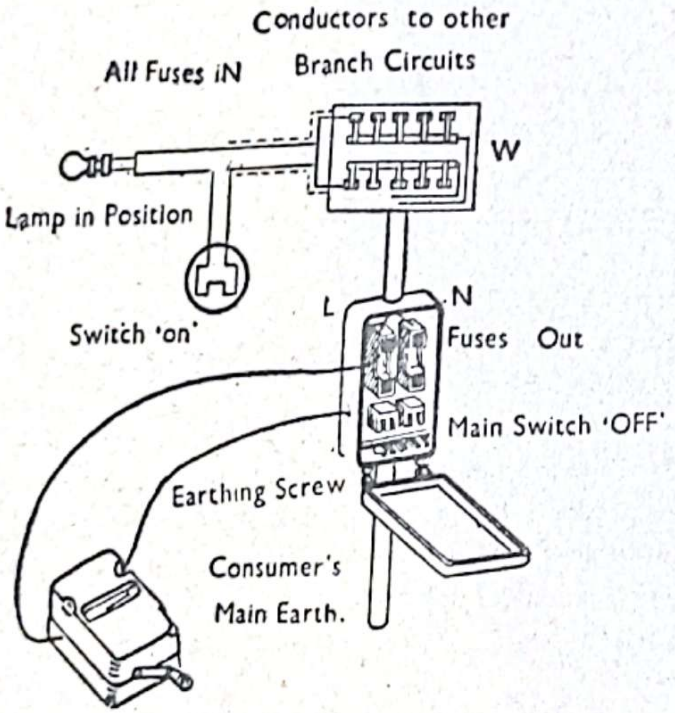
Disconnect the supply, as in the previous case, by opening main switch and withdrawing its main fuses. Remove all lamps. All fuses of the main distribution fuse board should remain. All single pole switches must be kept in the closed or "ON" Position. In the circuits having 2 way stair-case wiring two readings should be taken. One reading should include both switches in one "ON" position

and the other with both switches in the alternative "ON" position. This is to ensure that both inte switch wires are included in the test.

Now connect the two terminals of the Magger insulation tester to the two fuse contacts on th installation side, and render the test,

If the result of the test between the conductors is according to I.E.E. regulations, no further investigation is necessary. If the test does not meet the requirements of the regulations, withdraw all the fuses of main distribution fuse board and test each branch circuit individually between conductors until the faulty final sub-circuit is located.

Having established a final sub-circuit in which the fault lies, disconnect each component part of the circuit and test again to see whether the removal of these small sections has cleared the fault. It may



All Scale Pole Switches 'ON'
All Lamps in position

Fig. 2. Insulation test to earth on whole installation.

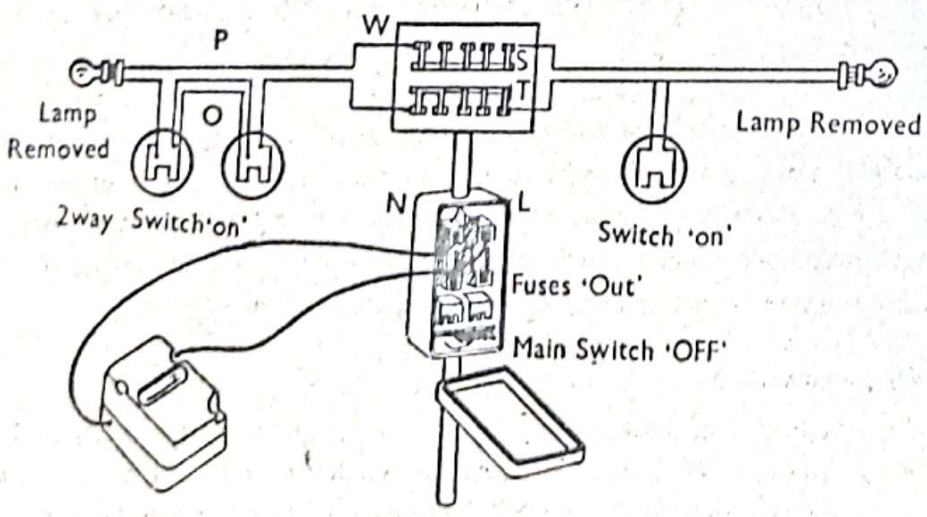


Fig. 3. Installation test between conductors on whole installation.

mentioned that faults only occasionally occur in ordinary straight runs of cable, and this is t the first place to look for trouble. It is much more frequent that faults both between nductors and to earth, occur at switches, in ceiling roses, in lamp-holders, in junction xes, etc.

In locating faults in a section of final sub-circuit in which several points are looped together, open e switch of the circuit, and apply the insulation test connecting the Magger insulation tester fuse and neutral link of the final sub-circuit at the distribution fuse board. If the fault as cleared it is apparent that it lies in the section of the final subcircuit. In may be in the nduit, switch, ceiling rose or lamp flexible cord. Test again removing each, one after another. however the fault has not been cleared open the switch of the circuit and repeat the test. If fter opening in turn each of the switches in the circuit the fault still persists, it is evident that it oes not lie in any of the wires between the switches and the lamp they control, but in switch feeds.

xample 1.

A wiring installations has eight single pole switches controlling eight light and fan points nd two switched socket outlets. Find the minimum acceptable insulation resistance between onductor or conductor and earth of a completed insulation when it is wired by (a) V.I.R. cable b) P.V.C. cable.

(a) Acceptable resistance for V.I.R. cable

$$= \frac{50 \text{ megohms}}{\text{No of outlets}}$$

$$= \frac{50}{20} = 2.5 \text{ megohms.}$$

(b) Acceptable ressistance for P.V C. cables

$$= \frac{12.5}{\text{No of outlets}}$$

$$= \frac{12.5}{20} = .625 \text{ Megohms.}$$

ample 2.

In the above example, if the installation is incomplete. What is the acceptable insulation istance between conductor or conductor and earth.

(a) Acceptable resistance for V.I.R. cable

$$= \frac{100}{\text{No of outlets}}$$

$$= \frac{100}{10} = 5 \text{ Megohms.}$$

(b) Acceptable resistance for P.V.C. cable

$$= \frac{25}{20} = 1.25 \text{ Megohm.}$$

arth continuity conductor :

A Magger insulation tester used for testing insulation is unsuitable for testing earth continuity ctor as the scale range of the instrument is very high and the testing pressure excessive. It will continuity and low resistance, but will not register an accurate reading of the resistance of continuity ctor. Instruments recommended for continuity testing are the bridge Magger, and earth fault loop fence tester.

(1) Bridge test :

Continuity tests on installations must be made with the circuit wiring dead. To do this turn the main switch "OFF" and as a precaution remove the main fuses. One circuit of the cable can be used as the return path of the current since its resistance can be worked out from its known length and appropriate tables. Connect the cable to the earth continuity conductor at the far end of the circuit under test. The bridge Magger should be connected between the cable fuse in the main switch at the installation side and earthing point. The resistance of the circuit so formed can be obtained by balancing the bridge. This resistance minus the resistance of the cable used as return path gives the resistance of the earth continuity conductor. This resistance shall not be more than one ohm for copper conductor of one half ohm for steel conduit.

(2) *Earth-fault loop impendence tester* :

The testing of earth continuity by earth-fault loop impedence tester of a current injection type in alternating current installations is very effective. The method uses an ammeter and voltmeter with alternating current. The use of alternating current is advantageous as it measures the effective impedence of the earth continuity conductor, which it offers under short circuit conditions to earth.

In order to test the impedence, one of the circuit cables is again used as the return path, and is joined to the earth continuity couductor at the farthest point of installation.

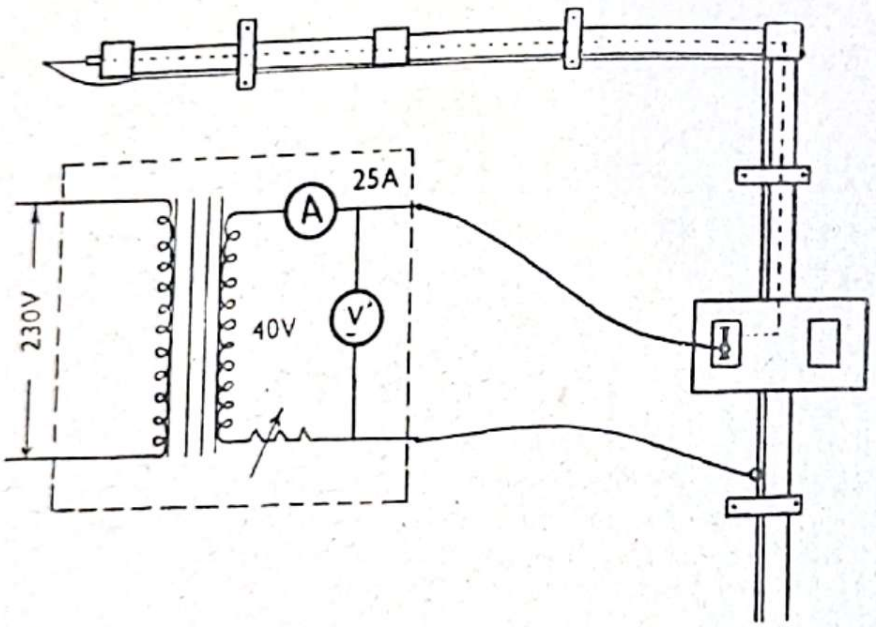


Fig. 4. Impedence test circuit.

The maximum voltage of the transformer secondary is 40 volts. By connecting the tester leads to the earthing point and the termination point of the cable at the main switch, an alternating current is passed through the complete continuity conductor. The current is adjusted by a rheostat to 1.5 times the current rating of the circuit, but need not exceed 25 amperes.

$$\text{The total loop impedence} = \frac{\text{Voltage}}{\text{current}} = \frac{\text{Reading of volt meter}}{\text{Reading of ammeter}}$$

The loop impedence also includes the resistance of the cable used for return path, and in order to determine the impedence of earth continuity conductor it should be deleted from the loop impedence.

The impedence of the earth continuity conductor should not exceed one ohm for copper conductor and a half ohm for steel conduit.

Example :

In determining the resistance of earth continuity conductor by alternating current method the ammeter and voltmeter readings obtained were 25 amperes and 28 volts. If 3/.036 cable (area of cross section .003 sq. inches) of length 20 yards was used as return conductor, find the resistance of earth continuity conductor.

Total resistance of cable and earth

continuity conductor $= \frac{V}{I} = \frac{28}{25} = 1.12$ ohms.

Resistance of 3/.036 cable $= P \frac{L}{A} = 7 \times 10^{-6} \frac{20 \times 3 \times 12}{.003}$

$= .163$ ohms.

The net effective resistance of continuity conductor $=$

$= 1.12 - .163$

$= .957.$

The value is acceptable as the resistance is less than one ohm.

———

EXERCISES X

1. What are I.E.E. regulations regarding (a) insulation to earth (b) insulation between conductors? How are they tested by a Magger ?

2. How will you establish the polarity of switches on live conductors using
   (a) a test lamp,
   (b) a continuity tester
   (c) a Magger ?

3. Give reasons why :
   (1) A switch is always placed on the live conductor.
   (2) The earthing resistance is kept up to one ohm.
   (3) A fuse is not provided in the neutral wire.

4. Describe the procedure you would follow and the instruments required to trace the possible causes of the following faults in an installation.
   (i) Failure of fuses with no load connected.
   (ii) Failure of main fuses on load.
   (iii) Reduced voltage at load terminals.
   (iv) "Shocks" from the frame work of equipment which is connected but not switched on.

5. Describe method of earth loop testing. Illustrate your answer with a diagram of a method employing current injection equipment.

6. Describe the method of testing the resistance of a metallic conduit installation, and state the acceptable values stipulated by I.E.E. Regulations.

7. A domestic installation having ten lights, six fans and eight plugs was wired with V.I.R. cable in concealed conduit. Find the minimum acceptable insulation resistance (a) between conductor and earth (b) between conductors when the installation is complete and when it is incomplete.

8. A domestic installation having 15 lights, four fans and five plugs was wired with P.V.C. insulated P.V.C. sheathed cable on teak-wood batten. Find the minimum acceptable insulation resistance (a) between conductor and earth (b) between conductors when the installation is complete and (c) when it is incomplete.

APPENDIX I

RESUSCITATION FROM ELECTRIC SHOCK

The result of an electric shock on the body is to affect the nervous system, and the muscles contract involuntarily. The muscles controlling the heart and breathing action sometimes are stopped, and the patient appears dead.

It is difficult to dogmatise the voltage to give a fatal shock. The resistance of the human body, when the skin is perfectly dry, is of the order of 30,000 ohm, but may be as low as 150 to 200 ohms when it is wet. In the later case a voltage as low as 100 volts has sometimes been fatal. Under normal circumstances a voltage higher than 250 volts is considered dangerous.

When an accident occurs, first disconnect the power supply from the circuit the patient is in contact with. In case the patient is above floor or ground level measures should be taken to prevent him from falling.

If the installation cannot be disconnected quickly from the supply remove the patient from contact with the circuit by breaking his contact by a dry stick of wood or by pulling his body with it if possible. If the circuit has low voltage (upto 250 to earth) the body of the patient may be pulled by hand holding the clothes wherever dry and out of contact with the body. For the safety of rescuer, it is important, to stand on dry wood or bundle, of dry clothes or any other insulating material available when he is pulling the patient. The use of one hand to touch the body of the patient gives a chance to rescuer to save himself if he becomes victim of shock.

If the patient is conscious he should be sent to hospital or nearest point of medical aid. In case the patient is unconscious but continues breathing, loosen his clothing about his neck, chest and waist to ease breathing, and sprinkle his face with water. Plenty of fresh air and a little sniff of amonia spirit some times help patient in recovery.

If breathing has stopped or the patient breathes with pauses and spasmodically immediately start artificial respiration. To start it, swiftly loosen the patient shirt collar as it hinders in breathing. Remove any muffler or turban he is wearing.

Free the mouth of all foreign objects. If the patient has false teeth remove them. If the patient has clenched his teeth his mouth must be opened. This is best done by placing the four fingers of each hand at the lower corner of the lower jaw with the thumbs on the edge of the chin in order to move the lower jaw forward. The lower teeth should then come somewhat in front of the upper teeth

in this forward position. If the mouth cannot be opened this way, a metal or wood piece may be carefully inserted between the rear molar teeth and the jaw opened.

Then lay the patient on his abdomen and turn his head on one side resting on one of his arm. Extend the other arm straight forward past his head and place a pad of clothes under his head.

Fig. Artificial Respiration

The rescuer should then perform the following operation. Kneel by the patient's side or across his body facing his head. Place both palms on the lower ribs with the fingers extending around the sides. Press the patient gradually and slowly for about three seconds by leaning forward on your hands. Relax the pressure by falling back into your original upright kneeling position for two seconds without lifting your hands from the patient. Repeat the forward and backward swinging motion 12 to 15 times a minute until the patient starts breathing or a doctor arrives to take charge.

APPENDIX II

RELATION AMONG UNITS

LENGTH

1 in. $= 2.54$ cm $= 0.0254$ m $= 8.3333 \cdot 10^{-2}$ ft.

1 ft. $= 12$ in. $= 30.480$ cm $= 0.30480$ m $= 3.0480 \cdot 10^{-4}$ km
$= 1.8939 \cdot 10^{-4}$ mile.

1 mile $= 5.280$ ft. $= 1.609 \cdot 10^{5}$ cm $= 1.609$ m $= 1.609$ km.

1 cm $= 0.3937$ in. $= 0.032808$ ft. $= 10^{-2}$ m
$= 10^{-5}$ km $= 6.2137 \cdot 10^{-5}$ mile.

1 km $= 10^{5}$ cm $= 10^{3}$ m $= 3.281$ ft $= 0.6214$ mile.

1 micron $= 10^{-6}$ m $= 10^{-4}$ cm.

AREA

1 cir mil $= 0.7854$ sq mil $= 7.854 \cdot 10^{-7}$ sq in.
$= 0.000507$ sq mm,

1 sq in. $= 1.2732 \cdot 10^{6}$ cir mils $= 10^{6}$ sq mils
$= 6.452$ sq cm $= 6.944 \cdot 10^{-3}$ sq ft.

1 sq ft. $= 144$ sq in. $= 929.0$ sq cm
$= 0.09290$ sq m $= 3.587 \cdot 10^{-8}$ sq mile.

1 sq mile $= 2.788 \cdot 10^{7}$ sq ft. $= 2.590$ sq km $= 3.098 \cdot 10^{6}$ sq yd.

1 sq cm $= 0.1550$ sq in. $= 10^{-4}$ sq m $= 1.076 \cdot 10^{-3}$ sq ft.

1 sq m $= 10^{4}$ sq cm $= 10.76$ sq ft $= 1.550$ sq. in.

1 acre $= 43.560$ sq ft.

VOLUME

1 cu in. $= 16.387$ cu cm $= 5.787 \cdot 10^{-4}$ cu ft. $= 1.639 \cdot 10^{-5}$ cu m
$= 1.639 \cdot 10^{-2}$ l $= 4.329 \cdot 10^{-3}$ gal.

1 cu ft. $= 1,728 = 2.832 \cdot 10^{4}$ cu cm $= 0.02883$ cu m
$= 7.481$ gal. $= 28.32$ l.

1 cu cm. $= 6.102 \cdot 10^{-2}$ cu in. $= 3.531 \cdot 10^{-5}$ cu ft $= 10^{-6}$ cu m
$= 2.642 \cdot 10^{-4}$ gal. 1 10^{-3} l.

1 cu m $= 10^{6}$ cu cm $= 35.31$ cu ft. $= 61.023$ cu in.
$= 1.308$ cu yd. $= 264.2$ gal. $= 10^{3}$ l.

1 gal. $= 231$ cu in. $= 0.1337$ cu ft $= 3.785$ cu cm
$= 3.785 \cdot 10^{-3}$ cu m $= 3.7851 = 4$ qt.

TEMPERATURE

Degree Farenheit $= \frac{5}{9}$ (F—32)°C.
Degree Centigrade $= \frac{9}{5}$ C + 32.

Units	Erg	Joule	Pt.-lb.	K.W.h.	H.P.-hr.	Kg -metre	Calories	B. Th. U.
1 erg	1	10^{-7}	7.373×10^{-8}	2.778×10^{-14}	3.723×10^{-14}	1.020×10^{-8}	2.389×10^{-8}	9.479×10^{-11}
1 joule (1 watt-sec.)	10^{7}	1	.7373	2.778×10^{-7}	3.723×10^{-7}	.1020	.2389	9.479×10^{-4}
1 ft.-lb.	1.356×10^{7}	1.356	1	3.77×10^{-7}	5.051×10^{-7}	.1382	.3239	1.285×10^{-3}
1 Kilowatt-hr.	3.6×10^{13}	3.6×10^{6}	2.65×10^{6}	1	1.341	3.669×10^{5}	8.582×10^{5}	3413
1 H.P.-hr.	2.686×10^{13}	2.686×10^{6}	1.98×10^{6}	.746	1	2.737×10^{5}	6.401×10^{5}	2546
1 Kg,-metre	9.81×10^{7}	9.81	7.236	2.725×10^{-6}	3.654×10^{-6}	1	2.344	9.301×10^{-3}
1 calorie	4.186×10^{7}	4.186	3.087	1.165×10^{-6}	1.563×10^{-6}	.4267	1	3.968×10^{-3}
1 B.Th.U.	$1,054\times10^{10}$	1054	778	2.93×10^{-4}	3.928×10^{-4}	107.5	252	1

RELATIONS BETWEEN VARIOUS UNITS OF POWER

	Watt	Kilowatt	H.P.	Kg.,metre per sec.	Ft.-lb. per sec.	Kg. calorie per sec.	B.Th.U. per sec.	Metric H.P.
1 Watt	1	.001	.00134	.102	.737	.000239	.000948	.00136
1 Kilowatt	1,000	1	1.34	102	737	.239	.948	1.36
1 H.P.	746	.746	1	76	550	.178	.707	1.014
1 Kilogram metre/sec.	9.81	.00981	.0131	1	7.23	.00234	.0093	.0133
1 Ft.-lb./sec.	1.36	.00136	.00182	.138	1	.000324	.00129	.00184
1 Kg.-calorie per sec.	4,184	4.184	5.62	427	3,090	1	3.97	5.69
1 B.Th.U. per sec.	1,055	1.055	1.415	107.6	778	.252	1	1.434
1 metric H.P.	736	.736	.986	75	542.5	.176	.697	1

APPENDIX III

I.E.E. CURRENT RATINGS SUBJECT TO VOLTAGE DROP

VULCANIZED RUBBER, P.V.C. OR PQLYTHENE INSULATED CABLES INCLUDING TOUGH RUBBER, P.V.C. LEAD AND ALUMINIUM SHEATHED TYPES

TABLE I—SINGLE-CORE

CONDITIONS INSTALLATION : Bunched and enclosed in one conduit, troughing or casing, or Bunched in free air or in an open trench.

Ambient temperature : 30°C (86°F)

Size of Conductor		2 Cables D.C. or Single phase A.C.		3 or 4 Cables Balanced Three-phase		4 Cables D.C. or Single phase A.C.	
Nominal Area	Number and Diameter of Wires	Current Rating	Approximate length of Run for 1-volt drop*	Current Rating	Approximate length of Run for 1-volt drop*	Current Rating	Approximate length of Run for 1-volt drop*
inch²	inch	amp	ft.	amp	ft.	amp	ft.
0015	1/.044	5	16	5	19	5	16
002	3/.029	10	10	10	12	10	10
003	3/.036	15	11	13	14	13	12
0045	7/.029	20	12	15	19	15	16
007	7/.036	28	13	25	17	22	17
1	7/.044	36	16	32	20	29	20
145	7/.052	43	18	39	23	34	23
225	7/.064	53	23	48	29	42	29
3	19/.044	62	25	56	32	50	31
4	19/.052	74	29	67	37	59	36
6	19/.064	97	33	88	42	78	41

* At rated current.

Increased by 1 ft. for D.C.

APPENDIX III

I.E.E. CURRENT RATINGS SUBJECT TO VOLTAGE DROP

VULCANIZED RUBBER, P.V.C. OR PQLYTHENE INSULATED CABLES INCLUDING TOUGH RUBBER, P.V.C. LEAD AND ALUMINIUM SHEATHED TYPES

TABLE I—SINGLE-CORE

CONDITIONS INSTALLATION : Bunched and enclosed in one conduit, troughing or casing, or Bunched in free air or in an open trench.

Ambient temperature : 30°C (86°F)

Size of Conductor		2 Cables D.C. or Single phase A.C.		3 or 4 Cables Balanced Three-phase		4 Cables D.C. or Single phase A.C.	
Nominal Area	Number and Diameter of Wires	Current Rating	Approximate length of Run for 1-volt drop*	Current Rating	Approximate length of Run for 1-volt drop*	Current Rating	Approximate length of Run for 1-volt drop*
inch²	inch	amp	ft.	amp	ft.	amp	ft.
.0015	1/.044	5	16	5	19	5	16
.002	3/.029	10	10	10	12	10	10
.003	3/.036	15	11	13	14	13	12
.0045	7/.029	20	12	15	19	15	16
.007	7/.036	28	13	25	17	22	17
.01	7/.044	36	16	32	20	29	20
.0145	7/.052	43	18	39	23	34	23
.0225	7/.064	53	23	48	29	42	29
.03	19/.044	62	25	56	32	50	31
.04	19/.052	74	29	67	37	59	36
.06	19/.064	97	33	88	42	78	41

* At rated current. Increased by 1 ft. for D.C.

This table is based on Table 12 of the I.E.E. Regulations (13th edition) and applies to wiring in buildings for the conditions specified. Ratings for larger rubber insulated cables up to 1.0 inch 2 are given in Tables 12 and 13.

Current ratings shown do not apply to earthed concentric systems where the metallic sheathing is used as the return conductor.

Ambient Temperature. For ambient temperatures other than 30°C (86°F multiply the current ratings and divide the lengths for 1-volt drop by the appropriate factor below :

Ambient air temperature	...	25°C(77°S)	35°C(95°F)	40°C(104°F)	45°C(113°F)
Rating Factor	...	1.13	.86	.69	.47

Grouping Factor Number of cables	...	6	9	10	12	18	20
Rating Factor D.C. or single-phase A.C. (2 cables per circuit)	...	.7	—	.6	—	—	.5
A.C. balanced three-phase (3 cables per circuit, excluding neutral)	...	.8	.65	—	.6	.55	—

VULCANIZED RUBBER INSULATED CABLES

TABLE 2—SINGLE-CORE

CONDITIONS OF INSTALLATION : Number of cables in run : 2.
(D.C. or single-phase A.C.)
Run in free air or open trench (for cables in troughing or casing, see note below)
Ambient temperature : 30°C(86°F).

Cable Sheath	Size of Conductor		Current Rating		Approximate length of Run for 1-volt drop*	
	Nominal Area inch²	Number and Diameter of Wires inch	D.C. amp	A.C. amp	D.C. ft.	A.C. ft.
T.R.S. or BRAIDED	.1	19/.083	160	160	34	31
	.15	37/.072	205	205	40	33
	.2	37/.083	250	250	43	33
	.3	37/.103	335	335	49	30
	.4	61/.093	425	425	52	23
	.5	61/.103	485	480	56	22
	.75	91/.103	630	610	64	19
	1.0	127/.103	780	740	73	18
LEAD SHEATHED	.1	19/.083	165	165	33	30
	.15	37/.072	215	210	38	30
	.2	37/.083	260	255	41	31
	.3	37/.103	345	335	43	29
	.4	61/.093	445	415	50	23
	.5	61/.103	500	465	54	22
	.75	91/.103	650	570	63	20
	1.0	127/.103	800	650	71	25
ALUMINIUM SHEATHED	.1	19/.083	165	160	33	31
	.15	37/.072	215	205	38	31
	.2	37/.083	260	235	41	33
	.3	37/.103	345	310	48	31
	.4	61/.093	445	350	50	27
	.5	61/.103	500	390	54	26
	.75	91/.103	650	460	63	25
	1.0	127/.103	800	525	71	25

* At rated current

This table is taken from Tables 14 and 15 of the I.E.E. Regulations (13th edition) and applies to wiring in buildings for the conditions specified. The ratings do not apply to cables run near iron, steel or ferro-concrete, or to earthed concentric systems where the metallic sheathing is used as the return conductor,

Ambient Temperature. For ambient Temperatures other than 30°C(86°F) multiply the current and divide the lengths for 1-volt drop by the appropriate factor below :

Ambient air temperature	...	25°C (77°F)	35°C(95°F)	40°C(104°F)	45°C(113°F)
Rating factor	...	1.13	.86	.69	.47

Grouping Factor. For two or more circuits run in free air or open trench, the ratings above are not reduced provided that a minimum clearance of six inches is maintained between circuits. Where the number of circuits exceeds four, a horizontal disposition is assumed.

Cables in Troughing or Casing. The ratings above for trefoil formation as used, are reduced by the following rating factors :

Number of cables, excluding neutral	...	3	6	9	12	18
Rating factor	...	.9	.72	.58	.54	.50

VULCANIZED RUBBER INSULATED CABLES

TABLE 3—SINGLE-CORE

CONDITIONS OF INSTALLATION: Number of cables in run: 3 or 4 (balanced three-phase)
Run in free air or open trench (for cables in troughing or casing, see note below) Ambient temperature: 30°C (86°F)

Cable Sheath	Size of Conductor		Current Rating A.C.		Approximate Length of Run for 1-volt drop*	
	Nominal Area inch²	Number and Diameter of Wires inch	Flat Formation amp.	Trefoil Formation amp.	Flat Formation ft.	Trefoil Formatinn ft.
T.R.S. or BRAIDED	.1	19/.083	155	140	38	44
	.15	37/.072	200	185	39	46
	.2	37/.083	245	220	39	49
	.3	37/.103	325	295	36	49
	.4	61/.093	425	360	26	47
	.5	61/.103	480	410	25	45
	.75	91/.103	610	520	22	41
	1.0	127/.103	735	630	21	36
LEAD SHEATHED	.1	19/.083	160	140	35	43
	.15	37/.072	205	180	34	47
	.2	37/.083	250	220	34	48
	.3	37/.103	325	290	32	48
	.4	61/.093	410	355	25	46
	.5	61/.103	460	400	23	44
	.75	91/.103	560	500	22	40
	1.0	127/.103	640	600	21	35
ALUMINIUM SHEATHED	.1	19/.083	155	140	36	43
	.15	37/.072	200	180	35	47
	.2	37/.083	230	210	37	50
	.3	37/.103	300	280	35	50
	.4	61/.093	345	325	29	50
	.5	61/.103	385	370	27	48
	.75	91/.103	455	420	27	48
	1.0	127/.103	520	500	26	42

* At rated current.

This table is taken from Tables 14 and 15 of the I.E.E. Regulations (13th edition) and applies to wiring in buildings for the conditions specified. The ratings do not apply to cables run near iron, steel or

ferro-concrete, or to earthed concentric systems where the metallic sheath is used as the return conductor.

Ambient Temperature. For ambient temperature other than 30°C (86°F) multiply the current and divide the lengths for 1-volt drop by the appropriate factor below :

Ambient air temperature	25°C (77°F)	35°C (95°F)	40°C (104°F)	45°C (113°F)
Rating Factor	1.13	.86	.69	.47

Grouping Factor. For two or more circuits, run in free air or open trench, the ratings above are not reduced provided that a minimum clearance of six inches is maintained between circuits. Where the number of circuits exceeds four, a horizontal disposition is assumed.

Cables in Troughing or Casing. The ratings above for trefoil formation as used, reduced by the following rating factors :

Number of cables, excluding neutral	3	6	9	12	18
Rating factor	.9	.72	.58	.54	.50

VULCANIZED RUBBER, P.V.C. OR POLYTHENE INSULATED CABLES* SHEATHED WITH TOUGH RUBBER, P.V., LEAD OR ALUMINIUM.

TABLE 4—TWIN, 3-CORE AND 4-CORE

CONDITIONS OF INSTALLATION : One cable in run.
In conduit troughing or casing or in free air or open trench.
Ambient temperature : 30°C (86°F).

Size of Conductor		One Twin-core cable D.C. or Single-phase A.C.			One 3-core or 4-core Cable Balanced Three-phase.	
Nominal Area	Number and Diameter of Wires	Current Rating	Approximate Length of Run for 1-volt drop		Current Rating.	Approximate Length of Run for 1-volt drop
			D.C.	A.C.		
inch²	inch	amp.	ft.	ft.	amp.	ft.
.0015	1/.044	5	15	15	5	18
.002	3/.029	10	10	10	8	14
.003	3/.036	15	10	10	10	18
.0045	7/.029	20	11	11	15	18
.007	7/.036	28	13	13	20	21
.01	7/.044	36	15	15	25	25
.0145	7/.052	43	17	17	30	29
.0225	7/.064	53	21	21	37	36
.03	19/.044	62	23	23	43	39
.04	19/.052	74	27	27	52	45
.06*	19/.064	97	32	32	68	52
.1	19/.083	140	37	36	98	60
.15	37/.072	180	42	40	126	66
.2	37/.083	218	47	42	153	69
.3	37/.103	284	55	44	199	73
.4	61/.093	342	62	44	240	72
.5	61/.103	394	66	42	276	70

* These ratings apply for P.V.C. insulated and polythene insulated cables to B.S. 2004 and B.S. 1557 respectively in which the maximum conductor size is .06 inch².

At rated current.

This table is taken from Table 13 of the I.E.E. Regulations (13th edition) and applies to wiring in buildings for the conditions specified.

Ambient Temperature. For ambient temperatures other than 30°C (86°F) multiply the current ratings and divide the lengths for 1-volt by the appropriate factor below :

Ambient air temperature	...	25°C (77°F)	35°C (95°F)	40°C (104°F)	45°C (113°F)
Rating factor	...	1.13	.86	.69	.47
Grouping Factor					
Number of cables	...	2	3	4	5
Rating factor	...	.8	.7	.65	.6

PAPER INSULATED OR VARNISHED CAMBRIC INSULATED CABLES* LEAD SHEATHED-BARE OR SERVED, AND LEAD SHEATHED AND ARMOURED-BARE OR SERVED

TABLE 5

TWIN, 3-CORE AND 4-CORE (1,1000 VOLT)

CONDITIONS OF INSTALLATION : One cable in run

In free air or open trench, spaced 1 inch from wall

Ambient temperature : 30°C(86°F)

Size of Conductor		One Twin-core Cable D.C.		One Twin-core Cable A.C.		One 3-core or One 4-core Cable, Balanced Three-phase	
Nominal Area	Number and Diameter of Wires	Current Rating	Aproximate Length of Run for 1-volt drop	Current Rating	Approximate Length of Run for 1-volt drop	Current Rating	Approximate Length of Run for 1-volt drop
inch²	inch	amp	ft.	amp	ft.	amp	ft.
.007	7/.036	52	6	52	6	42	9
.0145	7/.052	77	9	77	9	65	12
.0225	7/.064	99	10	99	10	83	14
.04	19/.052	140	13	140	13	120	18
.06	19/.064	180	16	180	15	150	21
.10	19/.083	250	19	250	19	210	25
.15	37/.072	315	22	315	21	270	28
.20	37/.083	380	24	275	23	325	20
.25	37/.093	440	26	430	24	375	32
.30	37/.103	500	28	490	25	430	33
.40	61/.093	600	32	580	25	520	33
.50	61/.103	700	34	660	25	570	33

At rated current

Ambient Temperature. For ambient temperatures other than 30°C(80°F) multiply the current ratings and divide the lengths of run for 1-volt drop by the appropriate factor below :

Ambient air temperature				
25°C(77°F)	35°C(95°F)	40°C(104°F)	45°C(113°F)	50°C(122°F)
Rating factor				
1.05	.95	.89	.82	.75
Ambient air temperature				
55°C(130°F)	60°C(140°F)	65°C(150°F)	70°C(158°F)	75°C(167°F)
Rating factor				
.6	.61	.53	.43	.30

FLEXIBLE CORDS—CONDUCTOR SIZES AND RATINGS

TABLE 6

Size of Conductor		Approximate Diameter of Conductor	Maximum Allowable Resistance at 20°C for Tinned Wires	Current Rating* Twin, 3-core or 4-core subject to voltage drop	Maximum permissible weight supported by Twin Flexible
Nominal Area	Number and Diameter of Wires				
inch²	inch	inch	ohm/1000 yds.	amp	lb
.0006	14/.0076	.034	42.03	2	3
.001	23/.0076	046	25.57	5	5
.0017	40/.0076	.057	14.71	10	10
.003	70/.0076	.076	8.41	15	10
.0048	110/.0076	.092	5.35	20	10
.007	162/.0076	.120	3.63	25	10

Conductor sizes and resistances from B.S. 7 : 1953

*Rating are based on Table 27 of the I.E.E. Regulations (13th Edition).

The resistances given are for straight single cores. For twisted twin and multicore flexible cords, an allowance not exceeding 5 per cent must be added for the extra length due to the lay of the cores .

APPENDIX IV

CAPACITY OF CONDUITS

Maximum number of single core cable that can be drawn into conduit. (250 and 660 volt grade V.R.I. braided and compounded, and P.V.C. insulated cable only)

Size of Cable		Light Gauge		Heavy gauge									
		$\frac{5}{8}$"	$\frac{3}{4}$"	$\frac{1}{2}$"		1"		1$\frac{1}{4}$"		1$\frac{1}{2}$"		2"	
Cross Sect. Area	No. of Dia of wires	250 V grade	250 V grade	250 V grade	660 V grade	250 V grade	660 V grade	250 V grade	660 V grade	250 V grade	660 V grade	250 V grade	660 V grade
0.0015	1/.044	6	8	7	...	13	...	20	...	...	...	...	...
0.002	3/.029	5	7	6	4	13	9	20	...	...	...	...	...
0.003	3/.036	4	6	5	3	10	6	16	...	...	...	...	...
0.0045	7/.029	4	5	4	2	9	5	13	9	...	...	...	...
0.007	7/.036	2	4	3	...	7	4	10	8	14	...	...	...
0.01	7/.044	...	...	...	...	5	4	8	7	11	9	...	...
0.0145	7/.052	...	...	...	...	4	3	7	5	9	7	...	...
0.0225	7/.064	...	...	...	...	3	...	5	4	7	6	12	...
0.03	19/.044	...	...	...	...	2	...	4	3	6	5	9	...
0.04	19/.052	...	...	...	...	...	...	3	2	4	4	6	6
0.06	19/.064	...	...	...	...	...	...	...	...	3	3	5	5
0.1	19/.083	...	...	...	...	...	...	...	...	...	...	...	3
0.15	37/.072	...	...	...	...	...	...	...	...	...	...	...	2

Note :—(a) This table is based on tables 10 and 11 of the I.E.E. Regulations (13th edition)

APPENDIX V

EARTHING CONDUCTORS

Sizes of copper wire aud strip for earth continuity conductors and earthing leads.

Cable Size		Copper Wires S. W. G.	Copper Strip size
Area	Mumber of diameter of wires		
sq. ins.			ins.
.0015	1/.044	14	...
.002	3/.029	14	...
.003	3/.036	14	...
.0045	7/.029	14	...
.007	7/.036	14	...
.01	7/.044	14	...
.0145	7/.052	12	...
.0225	7/.064	10	...
.03	19/.044	8	...
.04	19/.052	6	...
.06	19/.064	4	...
.1	19/.083	2	...
.15	37/.072	1/0	$\frac{3}{4} \times \frac{1}{8}$
.2	37/.083	3/0	$\frac{3}{4} \times \frac{3}{16}$ or $1 \times \frac{1}{8}$
.25	37/.093	...	$\frac{3}{4} \times \frac{1}{4}$
.3	37./103	...	$1 \times \frac{3}{16}$ or $1\frac{1}{2} \times \frac{1}{8}$
.4	61/.093	...	$1 \times \frac{1}{4}$
.5	61/.103	...	$1\frac{1}{2} \times \frac{3}{16}$
.6	91/.093	...	$1\frac{1}{2} \times \frac{1}{4}$
.75	91/.103	...	$2 \times \frac{3}{16}$
1.0	127/.103	...	$2 \times \frac{1}{4}$

APPENDIX VI

FUSE WIRE TABLE FOR TINNED COPPER WIRES

S.W.G.	Dia. in inches	Continuous current rating of fuse in amps.	Approximate fusing current
40	0.0048	1.5	3
39	0.0052	2.5	4
38	0.0060	3.0	5
37	0.0068	3.5	6
36	0.0076	4.5	7
35	0.0084	5.0	8
34	0.0092	5.5	9
33	0.0100	6.0	10
32	0.0108	7.0	11
31	0.0116	8.0	12
30	0.0124	8.5	13
29	0.0136	10.0	16
28	0.0148	12.0	18
27	0.0164	13.0	23
26	0.0180	14.0	28
25	0.020	15.0	30
24	0.022	17.0	33
23	0.024	20.0	38
22	0.028	24.0	48
21	0.032	29.0	58
20	0.036	34.0	70
19	0.040	38.0	81
—	0.044	43.0	98
18	0.048	45.0	106
17	0.056	65.0	135
16	0.064	73.0	166
15	0.072	78.0	197
14	0.080	102.0	230
13	0.092	130.0	295

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